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The Effect of Rein Type and Bit Type on Rein Tension in the Ridden Horse

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The Effect of Rein Type and Bit Type on Rein Tension in the Ridden Horse

By

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Abstract

An important area of Equitation Science is rein tension; which is used to control ridden and unridden horses primarily using the application of negative reinforcement. Rein tension is affected by several variables including the rider, horse and equipment, although not all aspects of these variables have been studied. The work undertaken for this thesis comprised of three separate yet interlinked sections. The first identified (by qualitative questionnaire) the most commonly used bridle, reins and bit types and why the equestrian population use them. The results produced determined which rein and bit types would be trialled in the second and third sections. Rubber reins were the most commonly used (49.45%); while the snaffle family were highlighted to be the most popular bit type (84.71%). Section two evaluated the rein tension applied by 5 rein types (rubber, continental, laced leather, thick leather and thin leather). Rein type significantly affected rein tension (One-way Analysis of Variance; $F_{4,1060}$=20.13; P<0.001); was highest for rubber (12.928±0.377N) and continental reins (12.399±0.54N) and lowest for laced (9.730±0.377N), thick (9.618±0.368N) and thin reins (9.157±0.352N). The third section aimed to produce baseline data for the snaffle family of bits. 14 bit types were trialled across 29 horse and rider dyads. Bit type had a significant effect on rein tension (One–way Analysis of Variance; $F_{13,506}$=18.35; P<0.001). Overall, the results show rein tension varies significantly with rein and bit type. Given the impact of rein tension on the horse’s welfare understanding these variables is essential for ethical and sustainable equitation.

Key words: Equitation Science, rein tension, rein, bit, negative reinforcement, welfare.

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1. Introduction

Any form of ridden or unridden work requires communication between the horse and the rider (McGreevy, 2007). Within Equitation these interactions are described as aids which are implemented through the use of the rider's hands, seat and legs (Egenvall *et al*., 2012; Doherty *et al*., 2017) and are used to control the horse (Hawson *et al*., 2014). Using aids the horse is taught to give a specific response to an applied signal with the reward generally being the release of pressure (Doherty *et al*., 2017a). Negative reinforcement is the most common method applied when training a horse (McGreevy, 2007) and is a part of conditioning (Warren-Smith *et al*., 2007) which is fundamentally reliant on timing of pressure release (Hemsworth & Gonyou, 1999, pp. 212; McGreevy & McLean, 2007; Eiseriö *et al*., 2013; McGreevy *et al*., 2017). Correct application of negative reinforcement is the immediate release of pressure on receiving a desired response, see Figure 1 (Christensen *et al*., 2011; Egenvall *et al*., 2012) and is dependent on understanding that the horse learns through sequences of stimulus-response-reinforcement (Fenner *et al*., 2017). In this instance the aversive stimulus would be the physical pressure applied to the horse from the bit, the reins, the rider's hands and or the rider's seat (Christensen *et al*., 2011); the pressure is then released to reward and reinforce the applied signal (Waran *et al*., 2007, pp. 163). The intended aim of reinforcement is to increase the likelihood of the response occurring again; for example, applying pressure to the reins to signal deceleration. The tension is released immediately on the horse displaying the correct response; therefore encouraging the response to be displayed again.

Figure 1. Negative Reinforcement (Fenner et al., 2017).

Legend: = the application of pressure,
= the release of pressure.

To be effective and humane the pressure applied is required to be minimal and released immediately once the desired response is given (McGreevy, 2007; McGreevy

& McLean, 2010). The timing of pressure release is essential as it determines which behavioural response the horse will associate with the applied signal (McGreevy, 2007; McGreevy *et al*., 2017). The response that is given immediately before the release of pressure will be the behaviour more likely to be re-displayed; in turn lowering the horse's motivational drive when the correct behavioural response is reinforced (McGreevy, 2007). As the optimal timing of pressure release has yet to be determined it is important to apply shaping (Waran *et al*., 2007, pp. 163; Egenvall *et al*., 2012) during training to minimise the likelihood of unwanted behaviours becoming learned. However Evengall *et al*. (2012) state that the majority of equitation literature recommends the release of pressure should be instant while the applied signals increase in lightness. Therefore a correctly conditioned horse will respond to the lightest of stimuli (Clayton *et al*., 2003) which Warren-Smith *et al*. (2007) describe as an aim of classical equitation.

Negative reinforcement is used to condition the horse to the lightest of signals; therefore when implemented correctly it will potentially improve training, performance and welfare (Fenner *et al*., 2017). However, when pressure release is incorrectly timed it can have the reverse effect (McLean & McLean, 2002; Christensen *et al*., 2011) leading the horse to become conditioned to respond with an unwanted behaviour, be unresponsive and may eventually result in habituation (Waran *et al*., 2007, pp. 162; Goodwin *et al*., 2008; Hall *et al.,* 2008*).* For instance, when accidental variations in applied pressure occur the horse may interpret the change as a signal. Heleski *et al*. (2009) suggest signal variations applied by the rider most commonly occur due to riding ability; if the rider is unable to adjust to the horses movements it can lead to excess pressure being applied (Eiseriö *et al*., 2013). Furthermore as complete freedom from pressure during ridden work is unavailable (McGreevy, 2007) it is essential for the horse to be able to discriminate between different forms of tension whether they originate from the horse or the rider. Therefore understanding the complexity and effect of multiple aids on how the horse learns and responds is important for maintaining a good welfare status for the individual animal being trained (Hawson *et al*., 2014). If not maintained it can cause the horse to not only display behaviours potentially indicative of conflict but may eventually lead to learned helplessness (Hall *et al*., 2008). This further highlights the requirement for research that objectively evaluates the horse and welfare (Randle & Waran, 2017;

Waran & Randle, 2017) in relation to training techniques (Christensen *et al*., 2011) and performance which can be provided through Equitation Science.

Two and a half million people in the UK ride, according to the 2015 British Equestrian Trade Association (BETA) national survey; which has significantly decreased from three and a half million in 2011 and over four million in 2009 (Williams, e.d, 2009, pg. 91). Of these two and a half million riders 96% ride for leisure purposes while 59% participate in non-affiliated competitions. The survey further highlighted the current female gender bias (74%; nine hundred and sixty-two thousand female riders to three hundred and forty-eight thousand male riders) within the equestrian industry (BETA, 2015). The number of riders in the age range of sixteen to twenty-four years was estimated to have increased from three hundred and sixty-eight thousand to four hundred and three thousand. The survey potentially reveals a substantial number of riders who are likely to have minimal or no knowledge or understanding of Equitation Science or The International Society of Equitation Science (ISES) along with its aims that include the first principles of training (ISES, 2017b). Williams (e.d, 2009, pp.91) highlight 43% of the UK population have an interest in some form of equestrianism while Doherty *et al*. (2017b) suggest veterinarians have poor knowledge of learning theory. The equestrian community is renowned for maintaining traditional strongly held beliefs and opinions that can impede change and better conditions for the horse; including the assumption that an absence of poor welfare equates to good welfare. Development of welfare policies tends to be based upon scientific evidence, however there is unlikely to be improvement in welfare without changes to the attitudes and values held by the general practitioner as evidence-based approaches contrast those observed in industry which are based upon traditional methods, opinions and fashion. These factors lead to slow transfer of knowledge between the academic and general practitioner within the equestrian community despite ISES having existed since 2007. For instance, Fenner *et al*. (2017) highlight that a large proportion of equestrian trainers lack understanding of how horses learn, including the theory and application of negative reinforcement. However it should be recognised that recently the equestrian industry is beginning to develop understanding as revealed by a career vacancy offered by the Horse Trust. The horse training position involved criteria that required knowledge of ISES, the first training principles (ISES, 2017b) and being interested in evidence-based methods. In conjunction with this positive progress, the key personnel within the National Equine Welfare Council (NEWC) are active equitation practitioners (NEWC, 2015) that are keen to embed findings of academic research into future welfare policies. This aligns with the main aim of ISES to improve the welfare of the horse and the relationship between the horse and the rider (ISES, 2017); which in turn will potentially further the link between the academic and general practitioner within the equestrian community.

Equitation Science is a continually developing discipline which aims to understand the interactions between the horse and rider in relation to training, performance and welfare (ISES, 2017a) through the application of scientific measurement and interpretation (McGreevy & McLean, 2010; Preshaw *et al*., 2017; Randle & Waran, 2017). The discipline is supported by ISES (2017a) which encourages objective research into the understanding, development and improvement of training, welfare and the associations between the horse and the rider in relation to the physiological, physical and psychological status of the horse (Randle *et al*., 2017). Therefore it can be argued that Equitation Science provides intriguing and critically important areas of investigation aiming to promote sustainable and ethical approaches to equitation (McGreevy & McLean., 2009; McGreevy *et al*., 2014; Randle & Waran, 2017; Randle *et al*., 2017). There is an increasing acknowledgement highlighted by Randle and Ashton (2010) of the understanding and role of learning theory within equitation and the recognition that it can improve both training and welfare of the horse.

Through rigorous experimental and theoretical scientific methods, the understanding of learning theory and an evidence-based approach (Dyson, 2017; Randle & Waran, 2017), Equitation Science is able to analyse and evaluate horse and rider interactions, training and performance (McGreevy *et al*., 2014; Preshaw *et al*., 2017). Randle *et al*. (2017) explain how Equitation Science research can be categorised into three sections: behavioural, physiological or measurements of the horse and rider interface. However, the majority of research remains within veterinary science and biology (Randle & Waran, 2017), resulting in a lack of focus regarding the impact of training and behaviour on learning and welfare. Therefore highlighting the requirement of Equitation Science as it underpins training with learning theory that is largely reliant on negative reinforcement

(McGreevy *et al*., 2017) through providing objective evidence-based research (Randle & Ashton, 2010; Randle & Waran, 2017) while minimising the application of alternative and unproven techniques and anthropomorphism.

Equitation research involves collection of a range of physical data from either the horse or the rider (Randle *et al*., 2017); for instance, the rider aids (rider's hands, legs and seat) are potentially analysed through measuring rein tension, saddle pressures, stride length and weight distribution (McGreevy, 2007; McGreevy *et al*., 2014; Randle & Ashton, 2010). As these types of research are dependent on the application of negative reinforcement it has the potential to determine and highlight the impact of both timing and consistency of pressure release on the horse (McGreevy & Boakes, 2007). For example, during training an applied signal in reality is a force applied to a surface area (McGreevy *et al*., 2014); and as McGreevy and McLean (2010) have previously stated the timing of pressure release is essential particularly when small interfaces between the horse and rider occur as the applied pressure will be greater. Therefore the necessity of Equitation Science can be further argued as research aims to investigate the impact of unintended and unnecessary pressures on the horse which may result in painful pressures, behaviours related to conflict, de-training and habituation (McGreevy, 2011; McGreevy *et al*., 2014; König von Borstel *et al*., 2017).

An important area of Equitation Science that is continually being developed and understood through evidence-based research is rein tension; which is used to control ridden and unridden horses through the application of pressure, i.e. negative reinforcement (Fenner *et al*., 2017; Preshaw *et al*., 2017). In the case of the ridden bitted horse, the rider's hand applies the pressure, it travels down the reins and is transferred to the horse's mouth via the bit (Lashley *et al*., 2014). This connection is commonly referred to by the general practitioner in non-scientific language as 'contact' (Randle *et al*., 2017). The reins are a recognised method of communication between the rider and horse (Randle & O'Neill, 2015; Dyson, 2017; Fenner *et al*., 2017) and are frequently used to regulate the horse's head and neck position (Manfredi *et al*., 2009; Kienapfel & Preuschoft, 2016) and the speed and direction of the horse's movement (Clayton *et al*., 2003; Clayton *et al*., 2011; Eiseriö *et al*., 2015) in both novice and experienced horses (Egenvall *et al*., 2012). Correct application and release of pressure on the reins is essential for effective and efficient communication with the horse without compromising welfare (Randle *et al*., 2017). However a fundamental question that has arisen within Equitation Science is: what is the optimum level of tension between the rider's hand and the horse's mouth (McGreevy, 2007; Goodwin *et al*., 2008). Egenvall *et al*. (2012) state that a light connection is preferred, while Warren-Smith *et al*. (2007) have previously recommended that it be as light as possible to avoid the horse habituating to increased levels of pressure. Similarly, the Fédération Equestré International (FEI) (2017) advocate lightness as a key element of riding and the connection be accepted without conflict irrespective of level or difficulty. For example, during dressage competitions judges are seeking a consistent 'contact' as looseness suggests discrepancies in maintaining applied tension with the horse's mouth (Eiseriö *et al*., 2015). Nevertheless this is an ideal; there is growing understanding that within practice 'contact' can be elusive and the degree of tension will be affected by the rider's level (Egenvall *et al*., 2012) and purpose along with the horse's response to signals (Eiseriö *et al*., 2015). As Randle *et al*. (2017) discuss it is an action that is rarely accomplished similarly as it will differ between each rider and attempt. However, there is a necessity for rein tension research in relation to welfare of the ridden horse as a consistently maintained connection with correctly timed pressure release is crucial for effective learning and training (Randle & O'Neill, 2015).

Rein tension research is continually being encouraged and supported by the FEI as the organisation is developing an understanding of the potential impact of the incorrect application of pressure on the horse's mouth, welfare and the importance of ethical and sustainable equitation (McGreevy, 2011). Therefore as a whole the equestrian industry is recognising the necessity for equipment that enhances training in relation to the welfare of both the ridden and unridden horse (Randle, 2014, pp.34). As Equitation research develops so does the use of technological devices; which in turn has further developed and validated scientific measurement and protocols (Pierard et al., 2015; Randle *et al*., 2017). For instance, since introduction rein tension gauges have enabled fifteen years of objective evidence-based research (Steenbergen, 2014, pp.7) in assessing the pressure interactions between the rider and horse. Although there is variation in methods and measures used including assessing accumulative pressure rein tension gauges have allowed researchers and practitioners to develop a further understanding of the impact of rein tension on ridden horse welfare and an analysis of the range of variables that effect the pressures applied (Steenbergen, 2014, pp.7).

Rein tension gauges are proving to be a valuable scientific method of collecting objective evidence-based data (Singleton, 2001; Egenvall *et al*., 2012) in order to determine the impact of rein tension in the ridden horse (Clayton *et al*., 2003; Randle *et al*., 2017). In previous peer-reviewed research three rein tension devices have been used: the MLP-100™ (Transducer Technologies: Clayton *et al*., 2003; Manfredi *et al*., 2005), Mini Low Profile (MLP) -75 load cell (Transducer Technologies, Temecula, CA: Heleski, *et al*., 2009; Manfredi *et al*., 2009; Clayton *et al*., 2011) and ReinCheck (Crafted Technology: Kuhnke *et al*., 2010; Christensen *et al*., 2011; Randle *et al*., 2011). More recently the Centaur Rein Tension Device Professional edition S2013 (Centaur Trainology BV: Steenbergen, 2014; Randle & O'Neill, 2015).The device enables the operator to analyse a variety of variables affecting rein tension including basic level of 'contact', compliance and self-carriage of the horse, lightness of applied signals and the difference between the left and right rein of direction and the rider's hands (Steenbergen, 2014, pp. 10). The device also provides real-time feedback which has the potential to be an invaluable training aid (Clayton *et al*., 2003; Lashley *et al*., 2014). However when collecting data there are limitations which affect the device that require consideration, including: range, sampling rate, calibration and data conversion (Pierard *et al*., 2015). Each rein tension gauge is only able to transmit the data up to a specific distance from the receiver, for example the Centaur Rein Tension Device Professional edition S2013 has a limit of up to 40M (Steenbergen, 2014); past this distance will result in breaks in the collected data. The sampling rate of the device is an important element of data collection; the tension between the horse and rider deviates constantly due to factors including the speed and direction of movement, therefore if the rate of sampling is low critical variations in the tension may not be detected or recorded (Pierard *et al*., 2015). The Centaur Rein Tension Device Professional edition S2013 has a sampling rate of a hundred samples per second; therefore rapidly recording variations in tension. It is essential that the devices are calibrated correctly otherwise the data collected will not be accurate or a true representation of the tension occurring. Calibration is also important in relation to humidity and temperature; it has not been determined at which point weather conditions effect the devices; therefore it is suggested that the data is collected in an environment that minimises this factor (Pierard *et al*., 2015). During collection the data is automatically converted from analogue tension to digital values for analysis. However this necessary conversion results in the loss of a large magnitude of data. To an extent this is can be controlled through the number of digital bits available, an increased number equals increased resolution and precision (Pierard *et al*., 2015). A further limitation is the current expense of purchasing the rein tension device which has prevented the use within day to day training (McGreevy, 2007; Clayton *et al*., 2011). Although, as the technology becomes more affordable, the general practitioner may be able to access the valuable training aid (Lashley *et al*., 2014) which will further promote good horse training, encourage the link between the academic and lay-person, further the knowledge of coaches (McGreevy, 2007) and ultimately have the potential to improve ridden horse welfare. However it is important to acknowledge that precision, accuracy, validity and reliability (Randle *et al*., 2017) of the device are not compromised when seeking an affordable alternative (Clayton *et al*., 2011) as it has the potential to result in a contradicting effect on the welfare of the ridden horse.

Rein tension is influenced by a wide range of variables, though during simultaneous investigation it becomes difficult to determine which variable is responsible for the applied pressure. However the effect of bits (Manfredi *et al*., 2009), rein type (Randle *et al*., 2011), nosebands (Randle & McGreevy, 2013) and attachments (Heleski *et al*., 2009; Clayton *et al*., 2011) may potentially be evaluated individually. When studying the impact of the rider it becomes more complex as it involves the entire human body and the body is also effected by the horse. Substantial research has been conducted into rider laterality (Kuhnke *et al*., 2010), posture (Hobbs *et al*., 2014), position (Kang *et al*., 2010), asymmetry (Symes & Ellis, 2009) and stability of wrist position (Terada *et al*., 2006). Christensen *et al*. (2011) and Clayton *et al*. (2011) suggest that the level to which the horse and rider have been trained along with previous experiences and individual differences, for instance, horse breed, age and sex may have a potential effect on rein tension. However as Eiseriö *et al*. (2013) explain it can be problematic to conclude whether the variations have occurred due to the rider or the horse and whether by accident or on purpose. Therefore in order to overcome this issue McGreevy *et al*. (2014) highlight the potential of technology to quantify the materials that separate the horse from the rider. Research that implements this method will potentially lead to validation or expulsion of training methods within learning theory that may result in improved safety, training, performance and welfare (Williams, e.d, 2009, pp. 129-130; Nevison, 2012).

When evaluating recorded rein tension the data are shown on computer software through a constant variation of peaks that differ in frequency and magnitude (Clayton *et al*., 2003; 2011; Eiseriö *et al*., 2013). However the tension is complex which results in a number of sources that may be responsible and are problematic to distinguish between (Eiseriö *et al*., 2015). Therefore research into rein tension endeavours to determine the impact of each individual variable. For instance, Clayton *et al*. (2011) research exposed the horse to be the source of the spikes shown in rein tension data. Ten percent of the horse's body mass is represented by the head and neck (Clayton *et al*., 2011); during movement the horse will nod into the rein contact (Clayton & Hobbs, 2017) which is then restricted by the rider's hands and arms. This nodding motion has previously been shown to correlate with the timings of the spikes i.e. stride frequency (Clayton *et al*., 2003; Clayton & Hobbs, 2017); while the frequency of the spikes coincide with the horse's gait (Kuhnke *et al*., 2010; Eiseriö *et al*., 2015). During walk and trot the data are shown on the graph through two peaks (frequency 1.8 and 2.6Hz respectively; Clayton *et al*., 2005). In trot this is due to the two-beat rhythm (Clayton *et al*., 2003; 2011; Dyson, 2017) which relates with each diagonal limb pair (Figure 2). Whereas during canter the data are shown through one peak (frequency 1.7Hz; Clayton *et al*., 2005) which correlates with the stride that is supported by the diagonal limb pair (Clayton *et al*., 2011; Dyson, 2017; Figure 3). Recently Egenvall *et al*. (2015) concluded that during walk 29% of the overall tension may be attributed to the rider with 27% from the horse; while in trot 20% to the rider and 7% to the horse. Although Clayton *et al*. (2011) revealed the horse to be the main contributor the impact of the rider on the rein tension data spikes needs consideration. During motion the rider should smoothly follow the horse's movements through co-ordination of the entire body (Clayton & Hobbs, 2017); therefore implementing an independent seat. Goodwin et al. (2008) describe an independent seat as the minimisation of random movement in the saddle due to balance. However the degree of impact on rein tension data is dependent on the level and experience of the rider. When evaluating rein tension it is difficult to perceive which variable effected the pressure; whether it was rider or horse factors including biomechanics, gait, transitions, direction and or the interface between the horse and rider (Egenvall *et al*., 2016b; Dyson, 2017). Clayton *et al*., (2011) therefore suggest in order to compensate for this difficultly the minimal, maximal and mean rein tensions should be analysed to produce a rounded evaluation of the pressure applied by the rider. In turn Randle (2012) highlighted the industry-wide requirement for continued gathering of objective data to determine the range of pressures applied by the rider to receive a desired response from the horse. Further objective evidence-based data has the potential to enhance both riding and training techniques; and may ultimately lead to improvements in ridden horse welfare (Warren-Smith *et al*., 2007; Randle, 2014 pp.34).

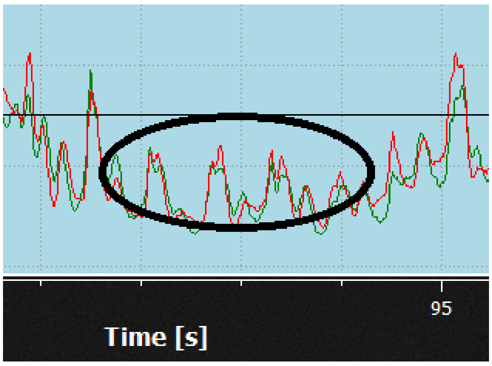

Figure 2. Rein tension data of trot (screenshot of authors' laptop during analysis).

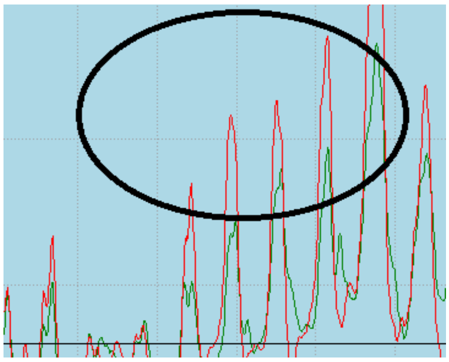

Figure 3. Rein tension data of canter (screenshot of authors' laptop during analysis).

Throughout equestrianism the reins have continued to be an important element of the interface between the horse and the rider. Reins are used to apply a signal to control and change the speed and direction of the horse's movement (Clayton *et al*., 2011; Randle *et al*., 2011; Egenvall *et al*., 2012) using negative reinforcement (Preshaw *et al*., 2017). For the ridden horse the rider will apply pressure to the reins bilaterally to signal deceleration and unilateral pressure to signal direction (Clayton *et al*., 2003; McGreevy & McLean, 2010). As Hawson *et al*. (2014) clarify deceleration signals that are efficiently responded to are essential for both safety (Williams, e.d, 2009, pp. 129-130) and welfare of the horse and rider. Hawson *et al*. (2014) explain that a signal applied by the rider should not be neutral, thereby the rider consistently maintains a constant pressure during ridden work only increasing the pressure when applying a signal. McGreevy & McLean (2010) define the correct application of pressure along this connection between the rider's hand and horse's mouth should be approximately 200g which is the equivalent of 2N. If the horse is unable to distinguish between the pressure that is meant to be neutral (i.e. the consistent 'contact') and the pressure applied for a signal it can potentially result in habituation and or learned helplessness (Hawson *et al*., 2014; ISES, 2017b).

According to Warren-Smith *et al*. (2007) during training riders are taught that applying a signal on the reins should be achieved through maintaining a light and consistent connection (Hawson *et al*., 2014) by using the weight of the rein (Ödberg & Bouissou, 1999). However in practice the use of the rein weight only is actually an infrequent occurrence; as Warren-Smith *et al*. (2007) results revealed tension applied on the reins by the rider was 100g heavier than that of the rein weight. This is an important finding as rein weight contributes to the level of neutral tension (McGreevy *et al*., 2014) and aligns with previous categorisations from Chamove *et al*. (2002) that rein tension is either tight, loose or inconsistent. Lashley *et al*. (2014) discuss that in general the novice rider will have a baseline 'contact' of 1 Newton (N) as minimal tension is applied and inconsistently maintained; while in contrast the experienced rider has been shown to sustain approximately 5 to 10N of tension through the reins. These values highlight the importance and requirement for further research into both 'contact' and consistency as McGreevy and McLean (2010) have stated 'contact' should be maintained at approximately 2N; however previous research implies that in practice it is not occurring.

Previous research has revealed large variances in recorded rein tension; both Preuschoft *et al*. (1999) and Clayton *et al*. (2003) found peak tensions to be between 40 and 75N during ridden work. In 2005 Warren-Smith *et al*. reported peak rein tension up to 20N and in a later study (Warren Smith *et al*., 2007) recorded peak tensions to be in the range of 40N with an overall mean tension of 9N. Whereas in contrast de Cartier d'Yves and Ödberg (2005) and Heleski *et al*. (2009) reported rein tension between 3 and 20N. Although there is a wide range in these reported values it does however correspond with data reported by Christensen *et al*. (2011) of recorded peak tension being approximately between 30 to 40N with an overall mean tension of between 6 and

10N. At walk rein tension has been recorded between 1.28N and 7.5N (Kuhnke *et al*., 2010). During trot Randle *et al*. (2011) recorded rein tension to be between 3.14N and 35N which decreased the range of values reported in an earlier study by Clayton *et al*. (2003) of tension at trot to be between 10 and 60N. Whereas Warren-Smith *et al*. (2007) found mean rein tension for trot to be 9N. Throughout canter rein tension has been recorded between 16.18N and 62.5N (Hawson *et al*., 2014). Reported rein tension data for the first three gaits align with Egenvall *et al*. (2016a) description that rein tension increases up the gaits. There is a wide range within these reported values; however each study varied in which movement the tension was evaluated in (Egenvall *et al*., 2016a), such as gait, transitions, direction, straight lines and or circles. Although each rein tension gauge used in the studies worked in a similar manner the range of capabilities and limitations for each were different. In conjunction development and measurement analysis of technology has resulted in the more recent studies producing data that has increased in accuracy and reliability (Christensen *et al*., 2011; Pierard *et al*., 2015); therefore the differences in reported values are to be anticipated. Christensen *et al*. (2011) discuss that the ridden horse will willingly accept tensions of up to 11N; however this is a substantial difference in comparison to the differences in values reported in previous studies. Therefore highlighting a current limitation and necessity for rein tension devices to have a capacity for measuring all the tensions applied across this wide range when attempting to address rein tension in relation to the welfare of the ridden horse.

Both McGreevy (2005) and Warren-Smith *et al*. (2007) reported greater rein tensions are required to achieve a halt transition than compared to any other response. The delay in receiving the correct response may be attributed to either the rider having poor skill or a lack of training or from the horse experiencing the manifestation of habituation. If the horse becomes habituated to rein tension then instead of decreasing the pace the horse will more likely lean on the bit (McLean, 2003); therefore resulting in an increase of applied pressure to achieve the desired response. However as Warren-Smith *et al*. (2007) highlight correct understanding of classical conditioning by applying other pressure signals (Waran *et al*., 2007, pp. 162) including the rider’s weight and legs will potentially reduce the reliance on rein tension to achieve a deceleration response.

Aids or signals are widely used including the reins to control transitions however there was a paucity of research concerning the potential impact of transitions between gaits upon rein tension. Egenvall *et al*. (2016a) aimed to develop further understanding by continuing earlier research from Warren-Smith *et al*. (2007); by evaluating the transitions between the first three gaits according to footfall sequence (Egenvall *et al*., 2016a). The results confirmed Warren-Smith *et al*. (2007) earlier finding that the downward transition to halt requires significant tension. However rein tension was recorded highest during transitions from canter to walk than compared from trot to walk which was associated with the least tension. The data also revealed upward transitions through the gaits were related with increased levels of rein tension. Egenvall *et al*. (2016a) further highlighted that transitions have a significant effect on pressure applied as a signal and therefore careful consideration needs to be undertaken when evaluating rein tension.

The variances in recorded rein tension data may also potentially be attributed to rider perception; Clayton *et al*. (2003) revealed there to be a substantial contrast between the rein tension data recorded and the level of rein tension the rider perceived to be maintaining. It may therefore be argued that rein tension is more of a subconscious feeling than a conscious concept (Lashley *et al*., 2014), resulting in an extensive difference between the tension the rider believes to be applying and what is actually applied (Randle *et al*., 2013). Clayton *et al*. (2003) explain that perception is extremely subjective and effected by proprioception, differences between the sensitivity of the riders right and left hands (Ödberg & Bouissou, 1999), the surface and texture of the object and whether it is static or dynamic (Warren-Smith *et al*., 2007), the rider’s level of grip force, and the overloading of sensory information originating from the environment, the horse and the rider. The level of rein tension applied also differs considerably between each individual rider (Randle *et al*., 2011). Leemans *et al*. (2016) revealed that rein tension for riders with gross motor skills to be substantially greater than compared to riders with fine motor skills. For instance the rider during fast muscle contractions can have a motor unit discharge rate of up to 120Hz while slow contractions are lower than 30Hz (Pierard *et al*., 2015). This highlights the necessity for rein tension devices to be able record rein tension at similar rate to the muscle contractions of both the horse and the rider. Leemans *et al*. (2016) concluded that shoulder position of the rider will also influence applied rein tension, the data revealed when riding a straight line, the riders with a clockwise position had a lower left rein hand tension than compared to riders with a counter-clockwise position. However to contradict this finding recent research conducted by Kuhnke and König von Borstel (2016) revealed riding style has a greater impact on rein tension than factors including horse or rider laterality. Therefore it is essential to acknowledge and understand that variations in rein tension that result from discrepancies in the rider including style, perception, position and biomechanics can cause application of excess pressures (Heleski *et al*., 2009; Eiseriö *et al*., 2013); which may potentially compromise the welfare of the ridden horse.

Ludewig *et al*. (2013) discuss how horses are often ridden with reins shortened to a length that contradicts the ideal either by the inexperienced rider desiring collection, for stretching the horse's muscles or from holding back the horse. The research revealed when applying shortened reins the horse displayed an increased number of conflict related behaviours, including tail swishing, mouth opening, flattened ears, forward movement of the ears and decreased bit chewing (Ludewig *et al*., 2013). These behaviours which are often referred as resistance or evasions and are categorised as behaviours which are indicative of conflict, potentially indicate that the horse found the tension aversive and stressful (McGreevy *et al*., 2005; Christensen *et al*., 2011; Henshall & McGreevy, 2014; König von Borstel *et al*., 2017). In comparison previous research conducted by Warren-Smith *et al*. (2007) which analysed rein tension between the horse and rider during specific movements revealed no portrayal of conflict related behaviours. Hence Warren-Smith *et al*. (2007) concluded the level of applied tension was not unnecessary and aligns with shortened reins having a negative impact on the occurrence of conflict related behaviours. At the opposite end of the spectrum McGreevy *et al*. (2014) discuss that longer reins will also potentially have a negative impact as it decreases the rider's ability to feel the horse's mouth. The absence of conflict related behaviours however, may be attributed to the level and efficiency of training the horse has previously undergone as avoiding tension by responding correctly is a key element of training (Christensen *et al*., 2011). Therefore it can potentially be assumed that the occurrence of conflict related behaviours will correspond with the level of applied rein tension (Egenvall *et al*., 2012). It should also be considered that horses are possibly punished when exhibiting behaviours which are indicative of conflict and may result in the horse showing no signs in response to an aversive stimulus or when suffering from pain and discomfort. Therefore re-highlighting the importance of appropriately applied negative reinforcement (ISES, 2017b); as incorrect use has the potential to cause resistance and conflict related behaviours (Waran *et al*., 2002; Warren-Smith *et al*., 2007). Sufficient understanding of negative reinforcement enables trainers to successfully decrease inappropriate and incorrect usage within everyday equestrianism (McGreevy & Boakes, 2007); which contributes to the importance and necessity of further research into the optimal level of pressure being applied to the horse in relation to ridden horse welfare (Warren-Smith *et al*., 2007).

When tack is incorrectly fitted there is the potential for a negative impact on the welfare of the ridden horse; yet Murray *et al*. (2015) highlighted there is a paucity of research into the determination of the effect of some types of tack, in this instance the bridle. Considering the range of different types and design of tack currently within the equestrian industry it is not surprising that there is confusion between what is necessary and what is fashionable. This is an important variable that needs consideration when collecting and analysing rein tension data as the use of inappropriate and ill-fitting tack will potentially affect the recorded data along with the welfare of the ridden horse. Advancements in technology have enabled the development of tack to be influenced and informed by the importance of horse welfare (McGreevy & McLean, 2010; Nevison, 2012). For instance Murray *et al*. (2015) research resulted in a bridle design that avoids the peak pressures that are usually found under the headpiece and noseband. The research showed that through changing the design of the bridle the pressures could be reduced resulting in increased muscle flexion and forelimb movement. Previously Murray *et al*. (2013) designed a girth that aimed to avoid peak pressures caused by limb protraction and flexion during show jumping. The study revealed that compared to standard designs the Fairfax Girth™ reduced peak pressures in areas which horses mostly commonly suffer from girth related sores (Murray *et al*., 2013). These improvements in tack design continue to highlight the necessity for further research to improve the welfare of the horse in relation to the development of equipment used throughout ridden and unridden work.

There are a considerable variety of rein types readily available on the equestrian market including rubber, leather and webbing (Randle *et al*., 2011). However there is minimal research documenting the effect of rein type on rein tension, the difference in tension between rein type and which rein type maintains the lowest or most consistent tension with the exception of a pilot study conducted by Randle *et al*. (2011). The study required thirteen human participants to maintain what they perceived to be a medium 'contact' on a model horse using six rein types (laced leather, narrow leather, rubber, webbing, dressage and eventing). The data were measured using a rein-o-meter apparatus and produced the first set of rein tension data to evaluate the effect of rein type on rein tension. The results revealed rein tension to be significantly affected by rein type; laced leather reins were associated with a greater tension than compared to narrow leather or webbed reins. The data showed a considerable variance in what a medium 'contact' is perceived to be by each rider. Randle *et al.* (2011) research further highlighted two things; firstly the necessity for further research into the different levels of 'contact' and secondly the continuation of research into determining the effect of rein type on rein tension.

The exact date of the human taming the horse is likely to remain unknown (Twain, 2011, pp. 28); however Waran *et al*. (2002) approximate it occurred five thousand years ago, whereas Budiansky (1997), Whay (2011, pp. 415) and Doherty *et al*. (2017) estimate an earlier date of six thousand years. Since domestication the horse has been used for a range of activities including working, leisure, sport and companionship (Quick & Warren-Smith, 2009). From taming a variety of techniques to control the horse's movement, speed and direction (Clayton *et al*., 2003) have been used. According to Twain (2011, pp. 28) the first method was a nose ring, similar to the type currently used on bulls. However this was ineffective in controlling both the ridden and unridden horse and was not applied after 2000BC. Since then the most common method for control and safety is the use of a bit that is fitted in the horse's mouth and originates from between 2300BC (Edwards, 2000) and 4000BC (Hawson *et al*., 2014) The use of a bit as a method of controlling the horse (Vernon, 1998, pp. 37; Batty-Smith, 2008, pp. 243) will only be successful if the horse has been effectively trained to respond to the application of negative reinforcement (Clayton et al., 2003). The horse is appropriately conditioned to understand that pressure applied by the rider is a signal and to react with the desired response (Eiseriö *et al*., 2015) i.e. a change in speed or direction; therefore employing negative reinforcement (Waran *et al*., 2007, pp. 163; Doherty *et al*., 2017). For instance, increasing the pressure applied to the reins during movement and then releasing the pressure immediately deceleration is received (McGreevy & McLean, 2010; Hawson *et al*., 2014), will successfully implement the core operant conditioning method therefore shaping the horse to the deceleration signal (Waran *et al*., 2007, pp. 163). To signal the horse for a response the rider will apply pressure to the reins which are attached to the bit (Warren-Smith *et al*., 2007) (Figure 4); the pressure is then dispersed across the surface tissues throughout the horse's mouth (Doherty *et al*., 2017). A correctly fitted bit contributes to the rider's ability to control the speed and directions of the horse's movements by maintain a light and consistent 'contact' with the horse's mouth (Manfredi *et al*., 2000); therefore rein tension will be affected by both bit shape and size. The bit consists of a mouthpiece with a ring on either end where the reins are attached (Tuke, 1965, pp. 25; Batty-Smith, 2008, pp. 245) and is suspended in the horse's oral cavity between the upper and lower mandible (Clayton *et al*., 2003). Both the ring of the bit and the cheek pieces of the bridle prevent the bit from being withdrawn from the horse's mouth (Doherty *et al*., 2017) when bilateral pressure is applied on the reins.

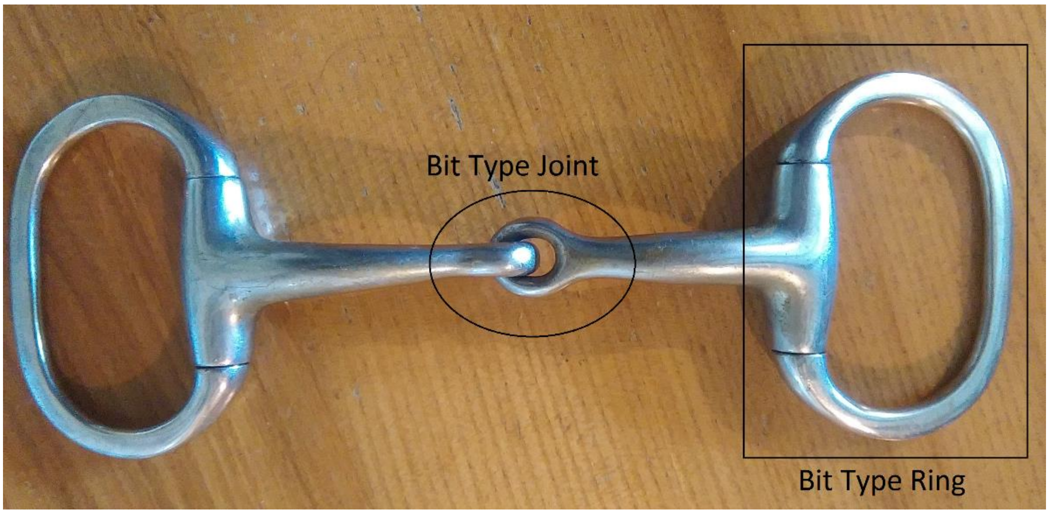

Figure 4. Components of a typical bit (picture taken by the author).

The bit is correctly fitted when there is a gap of 0.5cm between the ring of the bit and the outer surface of the horse's lips, i.e. one finger width (Vernon, 1998, pp. 32; Manfredi *et al*., 2005) as it will avoid pinching of the skin. Although the size and length of the bit when fitting is comparative to the oral structures of the horse's mouth as it will determine the level and area to which the pressure is applied (Doherty *et al*., 2017); the pressure distribution will also be influenced by the fitting of both the bridle and the bit, the position of the horses head and neck, how the horse holds the bit and the anatomy of the horse's oral structures (Eiseriö *et al*., 2015). However as Dyson (2017) discusses there is no industry standard (scientifically supported or not) for bit fitting. The pressure applied to a correctly fitted bit is usually spread through the centre; whereas the pressure applied to a bit that is too long results in pressure being spread over a greater surface area of the horse's oral tissues. In addition application of asymmetric pressure will cause the bit to travel laterally dispersing the pressure across the horse's lips and bars of the mouth (Doherty *et al*., 2017). Nevertheless Eiseriö *et al*. (2015) previously speculated that the specific distribution of the pressure across the bit is still undiscovered and was further confirmed by a later observation from Doherty *et al*. (2017) that the exact impact of an incorrectly fitted bit has yet to be determined.

When in use the bit is designed to disperse pressure applied by the rider to different regions of the horse's head (Quick & Warren-Smith, 2009); although mainly across the oral tissues that are situated below the mouthpiece (Clayton *et al*., 2003). These areas include the tongue, lips, gums, diastema, bars and roof of the mouth, chin grove, lower mandible, hard palate and the nuchal crest (Vernon, 1998, pp. 15-17; Waran *et al*., 2002; Clayton *et al*., 2003; Batty-Smith, 2008, pp. 243). However the amount and area that the pressure is applied to depends on the shape and size of the bit. A correctly fitted bit maintains constant pressure with the lips and a sporadic contact with the hard palate, premolar and canine teeth (Clayton & Lee, 1984; Engelke & Gasse, 2003). The pressure dispersal throughout the oral cavity is also monitored by the horse's tongue as it acts as a protector for the bars of the mandible (Björnsdóttir *et al*., 2014). According to Cross *et al*. (2017) there is an average gap of approximately 34mm between the horse's upper and lower mandibles and that the thickness of the bit mouthpiece is between 14 and 16mm; however Lashley *et al*. (2014) report that the most commonly sized bit used by the equestrian industry is 20mm. Engelke and Gasse (2003) explain that although the relationship between the horse's oral structures and the bit is dependent on bit type in the majority of cases the horse's tongue maintains the greatest contact with the bit;

therefore receiving the main proportion of pressure (Manfredi *et al*., 2005). Doherty *et al*. (2017) further confirm by explaining that due to the position of the bit the tongue actually covers the bars of the mouth, consequently receiving the majority of the tension applied by the reins and bit; unless the tongue is over the bit or has been retracted (Engelke & Gasse, 2003). McGreevy *et al*. (2014) suggest that the horse's mouth never evolved or was intended to accommodate a bit as there is minimal room for it; and is the reason why the bit presses the tongue against the bars of the mouth. McGreevy *et al*. (2014) further explain that through the use of fluoroscopic imaging (as conducted by Clayton & Lee, 1984; Manfredi *et al*., 2005) the bit actually sits on the horse's tongue instead of the bars of the mandible which contradicts an earlier thought by Clayton *et al*. (2003). Therefore the application and use of incorrectly sized bits (Cross *et al*., 2017) generates crucial questions regarding the welfare of the ridden horse.

Edwards (2000) report the first type of bit was a simple wooden straight bar mouthpiece; since then it has developed most commonly into stainless steel (Quick & Warren-Smith, 2009). There are an extensive assortment of bit types on the equestrian market (Tuke, 1965, pp. 24; Doherty *et al*., 2017) with other types including vulcanite rubber, copper, sweet iron and artificial nylon or plastic materials (Vernon, 1998, pp. 30-31; Batty-Smith, 2008, pp. 244). Tuke (1965) divided bits into three main family groups, Snaffle, Double and Pelham; whereas others use further categories such as the Gag and Hackamore (Batty-Smith, 2008, pp. 245).

It is essential to understand that one of the key challenges when evaluating rein tension is the difficulty in determining whether the pressure originated from the horse or rider (Clayton *et al*., 2011). The data are displayed as a constant variation of magnitude as a result of the rider's cues and the horses stride cycle (Clayton *et al*., 2003; Eiseriö *et al*., 2013). The level of applied tension also depends on the horse's reaction to bit pressure (Clayton *et al*., 2011; Egenvall *et al*., 2012; Eiseriö *et al*., 2015). As the rider increases the pressure applied on the reins it constricts the ring of the bit and the pressure is transferred to the mouthpiece. However it should be noted that the pressure applied to the reins does not entirely relate to the distribution of pressure across the horse's mouth and or surrounding areas (Pierard *et al*., 2015). Therefore due to bit type having a substantial effect on how the pressure applied to the reins is converted into concentration and distribution within the horse's mouth it is essential that the type of bit used within research is reported. The action of each bit is different (Waran *et al*., 2007, pp. 153) and is influenced by the horse's mouth, positon of the horse's head, the rider's hands (Batty-Smith, 2008, pp. 243) and the design, thickness and material of the bit (McGreevy *et al*., 2012). In turn each bit will affect the contact and distribution of pressure across the horse's oral tissues (Doherty *et al*., 2017). Bit types that have single joints move dorsally (Manfredi *et al*., 2009), distribute the pressure applied by the rider across the tongue and hard palate (McGreevy *et al*., 2014) and are known to have a nutcracker action. In comparison double jointed bits are believed to decrease the likelihood of movement in a dorsal direction (Clayton, 2005). It is understood that bits with a non-levered bits only apply pressure to the mouth whereas a lever motion will apply poll pressure (Benoist & Cross, 2016a) and has become a wide topic for debate. Cross *et al*. (2017) discuss the normal action of a lever bit is dependent on whether the environment it is situated in is fixed. However this is not the case with the horse's mouth and therefore does not provide an ideal location. The study conducted by Cross *et al*. (2017) revealed that levered bits produce considerable supressed pressure to the horse's poll and therefore is an area of concern regarding horse welfare and requires further development to determine the potential implications on both the behaviour and training of the horse.

Doherty *et al*. (2017) discuss that even though there is an extensive range of bit types that are categorised by effectiveness there is still a lack of understanding into the precise action of specific types. It is often thought that the thinner the bit the lighter and kinder it will be, however it is a common misconception (Batty-Smith, 2008, pp. 246); thicker bits are actually safer for maintaining the welfare of the horse as the thinner the mouthpiece the greater severity of action (Tuke, 1964, pp. 25; Vernon, 1998, pp. 37). However it should be remembered that bit width is only one mechanism used to influence severity and that the wider the size of the bit the greater the interface between the bit and the horse's mouth; meaning the pressure applied to the bit is spread over a larger surface area. Therefore an increased degree of pressure is required to receive the same response desired from the horse (Manfredi *et al*., 2009; Eiseriö *et al*., 2013) as when pressure is applied to a smaller width bit. If this knowledge is misunderstood it is a worrying consideration as Warren-Smith *et al*. (2007) discuss how horses can quickly become habituated to bit pressure. In turn leading to a repeated sequence of the rider increasing the applied pressure, the horse becoming habituated and the rider again increasing the pressure. However conversely a correctly fitted bit used wrongly will also result in similar effects including the potential of physical injury. McGreevy and McLean (2010) explain that continued exposure to an increase in pressure applied by the rider will result in the horse becoming confused and will potentially end with an outcome of learned helplessness. The occurrence of excess pressure being applied has commonly been associated with discomfort and pain in the horse's mouth (Warren-Smith *et al*., 2007; Manfredi *et al*., 2009; Eiseriö *et al*., 2013). This highlights the continuation of research to further understanding of the effect of bit type along with its potential impact on rein tension and ridden horse welfare in respect to the traits of the individual horse including conformation and level of experience.

According to Cook (1999) the use of a bit can result in discomfort and injury to the horse as it is an invasive and aversive method of control (Fenner *et al*., 2017). Doherty *et al*. (2017) discuss a further gap within research by highlighting the necessity of further understanding into how bit pressure affects the oral structures of the horse's mouth (Engelke & Gasse, 2003). Previous research (Lancker *et al*., 2007) has delved into the physical damage that incorrectly fitted or misuse of the bit can have on the ridden horse; resulting in a number of problems being reported (Batty-Smith, 2008, pp. 244; Quick & Warren-Smith, 2009). Firstly, the physical damages include ulcers, lesions and or abrasions of the oral cavity including the lips, tongue and bars of the mandible (Tell *et al.,* 2008; Björnsdóttir *et al*., 2014; Eiseriö *et al*., 2015). Oedema of the soft tissues, erosions to the mucosa, periosteal reactions and exostoses (Björnsdóttir *et al*., 2014). Dorsal displacement of the soft palate and facial neuralgia (Cook, 1999; Warren-Smith *et al*., 2007; Christensen *et al*., 2011); bone spurs in the diastema (Cook, 2002) and damage to the second premolars (Johnson & Porter, 2006). Secondly, an incorrectly fitted bit may also increase conflict related behaviours including licking, chewing, mouthing of the bit, moving the tongue over the bit, leaning on and grabbing the bit, headshaking, bucking, rearing and bolting (Cook & Strasser, 2003; Manfredi *et al*., 2009; Doherty *et al*., 2017). Thirdly an incorrectly fitted or used bit may affect the horse's flexibility, energy, forward motion, stride length, self-carriage and cause the horse to become heavier on the forehand (Cook, 1999; Cook & Strasser, 2003; Quick & Warren-Smith, 2009); which will potentially impact rein tension.

An incorrectly fitted bit can result in physical damage (König von Borstel *et al*., 2017) but potentially may also have a psychologically negative affect on the horse (Ödberg & Bouissou, 1999; Christensen *et al*., 2011). For instance, McGreevy *et al*. (2005) state that the ridden horse's balance can be improved through working the horse 'on the bit'; however this concept is commonly incorrectly applied by the rider misinterpreting flexion in the poll and maintaining an increased level and duration of tension (Cook, 1999; Warren-Smith *et al*., 2007). Therefore highlighting that the rider is influential in terms of a bit causing damage, which is of some concern when considering the welfare of the ridden horse as there is a potential for habituation to the increased level of tension (Ödberg & Bouissou, 1999); while the position will also disperse more pressure across the horse's tongue and lower mandible (Doherty *et al*., 2017). When habituation occurs the rider has two choices, to either change the severity of the horses bit (McGreevy *et al*., 2014) or increase the level of applied pressure. Both these choices will have a similar result; a sequence of increased pressure followed by further habituation (Tuke, 1965, pp.24; Miller 1995; Waran *et al*., 2007, pp. 162; Warren-Smith *et al*., 2007). However the rider's ability requires consideration as a low severity bit with a poor rider may still result in physical damage and a lack of learning. Similarly, an increase in pressure applied by the rider may cause an unwanted reaction such as behaviours that are indicative of conflict instead of the desired response (Egenvall *et al*., 2012; McGreevy *et al*., 2014); for instance the horse 'pushing against the bit' or 'moving away from the bit'. McGreevy and McLean (2007) propose that these behaviours are exhibited by the horse endeavouring to be alleviated of bit pressure (McBane, 1994, pp.144). The behaviour may potentially occur due to the horse having minimal understanding of the deceleration signal through unsuccessful learning and training (McGreevy & McLean, 2007) or from an incorrect application of negative reinforcement and pressure release. However the assumed behaviour may also be attributed to discomfort originating from an incorrectly fitted bit (McBane, 1994, pp. 144; Egenvall *et al*., 2012). Doherty *et al*. (2017) also suggest that behaviours which are indicative of conflict may be related to the occurrence of bite marks on the horse’s bit; however mouthing of the bit has generally been accepted as an indicator of the horse accepting the bit (Kapitzke, 2004). Therefore as a result of the horse’s sensitive mouth (Cook, 1999) continued exposure to excessive pressures has the potential to compromise the ridden horse’s welfare (Ödberg & Bouissou, 1999) as a result of learned helplessness (Fenner *et al*., 2017).

Cook and Mills (2009) refer to a study where the data included 200 undesired behavioural reactions and 40 diseases that apparently transpired as a result of the use of a bit (Cook, 2009). However in equestrian sports specifically competitions regulatory bodies stipulate the use of a bit (Cook & Mills, 2009). Furthermore the FEI desire that the ‘contact’ between the horse and the rider be continuously consistent and achieved by the horse seeking the pressure (Clayton *et al*., 2011; Eiseriö *et al*., 2015; FEI, 2017); it should be noted that a definition was not supplied. However rein tension data has revealed that what appears to be consistently maintained ‘contact’ in fact produces a wide range of values (Clayton *et al*., 2011). For instance, at walk 40N was recorded whereas in canter values of 70N have been determined; which has been further demonstrated by research into the horse stride cycle (Eiseriö *et al*., 2013; Egenvall *et al*., 2015). In addition this further confirms the difficulty that judges have in evaluating the level of tension being maintained throughout competitions (de Cartier d’Yves & Ödberg, 2005; Goodwin *et al*., 2008; Eiseriö *et al*., 2015). The fact that the horse will push against the bit not only prevents the level of applied rein tension from being minimised (Clayton *et al*., 2011) but also the potential for the horse to become habituated to rein tension (Egenvall *et al*., 2012). Furthermore when considering the welfare of the ridden horse it raises the point that consistency is of greater importance than minimising the level of tension applied. Hawson *et al*. (2014) highlight it is essential that knowledge regarding rein tension be furthered in relation to safety of both the horse and rider when using bits that have the potential to be incorrectly implemented. Therefore according to Doherty *et al*. (2017) equestrian regulatory bodies are currently promoting objective evidence-based research (de Cartier *et al*., 2005; Warren-Smith *et al*., 2007; Warren-Smith & McGreevy, 2008; Randle *et al*., 2017) to review, guide and support regulatory decisions and standards when judging in relation to traditional and novel bits (Casey, 2013) to improve and maintain the welfare of the horse (Campbell, 2011, pp. 201).

Unevenness of the rider’s rein hands has been shown to influence how applied pressure is distributed across the bit (Doherty *et al*., 2017). Clayton *et al*. (2011) highlight that an earlier study (Warren-Smith & Bronicki, 2009) into rein tension revealed a substantial difference in pressure applied to each rein by the riders hands (left rein: 1.85N, right rein: 2.12N). However these results are contradicted by Hawson *et al*. (2014) which suggest there is more evidence to confirm riders actually apply higher levels of pressure to the left rein than compared to the right rein. Although Clayton *et al*. (2003) explain the horse will also show sidedness through preference of one rein and this may potentially contribute to rider handedness. The more the rider elevates the hands the further the bit will be drawn in a dorsal direction; which is worrying as if the rider is maintaining a correct position the bit normally moves in a caudal, ventral or caudo-ventral direction. Nevertheless training of both the horse and rider aims to maintain symmetry in both reins to prevent the horse from experiencing excess or unintended pressure (Clayton *et al*., 2003). When shaping is correctly applied it teaches the horse to respond to a light signal including those associated with the rider’s seat; therefore potentially preventing application of higher pressures (Waran *et al*., 2007, pp. 163; Hawson *et al*., 2014). McGreevy and McLean (2010) highlight the necessity for the horse’s ability to differentiate between a baseline ‘contact’ and pressure applied to signal a response (Hawson *et al*., 2014). However Warren-Smith *et al*. (2007) emphasise the novice rider would struggle to employ or maintain light pressure consistently compared with the experienced rider. When pressure applied to the reins is excessive or unintended the discrepancies may have occurred due to the rider being unable to successfully adjust to the horse’s movement (Heleski *et al*., 2009). When variations occur it can compromise a vital step of negative reinforcement, the release of pressure (McGreevy & McLean, 2007; Eiseriö *et al*., 2013); if incorrectly implemented it may potentially result in confusion (Saslow, 2002), habituation (Waran *et* al., 2007, pp. 162), learned helplessness (Fenner *et al*., 2017) and eventually compromising horse welfare.

There is growing popularity of noseband use within equestrianism however there is minimal evidence documenting the potential effect on the horse's sensitivity to the bit (Randle & McGreevy, 2013). The introductory investigation by Randle and McGreevy (2013) revealed that loosening the noseband by one hole resulted in application of considerably higher rein tensions. However the exact effect that nosebands may have on bit sensitivity requires further development to determine the implications on horse welfare. It is becoming widely accepted that bits can result in physical and psychological problems however there is a paucity of research regarding bit sensitivity in relation to welfare and performance of the horse (Vanderhost *et al*., 2013). Randle and Wright (2013) examined the rider's perception of the degree of pressure needed to receive a desired response using four bit types (Eggbutt Snaffle, French-Link Snaffle, Pelham and 3-ring Continental Gag with the rein on the bottom ring). The data revealed significantly increased levels of rein tension were applied to the Snaffle bit type in comparison to either the Pelham or the Continental Gag which may be attributed to lower severity. However an interesting finding was there was no significant difference in rein tension between the left rein or the right rein hands of the riders; meaning there was no preference to handedness being displayed. Randle and Wright (2013) go on to report that rider's do understand bit type severity as it is assumed that it takes higher levels of tension to receive any response with the use of a Snaffle bit than any other type. These findings align with Vanderhost *et al*. (2013) research which emphasised horses ridden with a thinner bit than compared to a thicker bit exhibited decreased signs of stress and less fluctuations in the head and neck position. In relation to welfare understanding bit type severity is essential as ethical equitation implores that stress of the ridden horse be minimal and warranted (McGreevy *et al*., 2017).

Rein tension is affected by several variables including the rider, horse and equipment, although not all aspects of these variables have been studied. The work undertaken for this thesis comprised of three separate yet interlinked sections with an aim of producing a baseline of data for future research. Currently there is an abundance of both rein and bit types available within the equestrian market that are used from every day to training to competitions (McGreevy *et al*., 2014); along with this in the case of bit type some are used for overcoming both training and performance problems. The first study aimed to identify the types of reins and bit that the equestrian population use most commonly and why through the use of a qualitative questionnaire. The survey was relevant to the entire body of the research as the results would indicate which rein and bit types would be trialled in the second and third investigations. The second study aimed to further investigate a preliminary study conducted by Randle *et al*. (2011) into the effect of rein type on rein tension through a quantitative study. The objective of the study was to determine the difference in tension between the rein types trialled and evaluate which maintained the least and most consistent rein tension in the ridden horse. Currently there is a wide range of research into bit type in relation to the effect on rein tension however there is a paucity of baseline data. The third study aimed to provide quantitative baseline bit type data for the bits in a specific family chosen by the results of the survey; with an objective to describe and compare the response of different bit types, in order to sufficiently describe the pattern of rein tension and facilitate comparisons across different studies with the interest of benefiting the welfare of the ridden horse.

2. The Survey

The qualitative questionnaire was designed with a main aim of identifying the different types of bridle, reins and bit that the equestrian population use as currently there is a wide range of products available within the industry. The results would be used to inform the two further studies that aimed to investigate the effect of rein type and bit type on rein tension in the ridden horse. The research further branches into the interactions between the horse and the rider with the aim of further improving the relationship between the academic and the general practitioner with respect to the welfare of the ridden horse.

2.1 Method and Materials

2.1.1. The Survey

The main objective of the survey was to investigate the range of different types of bridle, reins and bits used by the equestrian population and to ascertain reasons for use. The survey used can be in seen in Appendix 1. The first five questions were designed to determine the rider's connection with the horse including specific aspects of riding purpose and length of time the rider has ridden for (years). These questions were expected to generate data that would enable comparison with the results that originated from the 2015 survey carried out by BETA. The only multiple choice question within the questionnaire regarded sex of the rider; the remaining questions were left open to interpretation as the author did not wish to lead the respondent in any manner. The final three questions of the survey were related to the riders use and preference of bridle type including the type of reins and bit used during ridden work; these questions aimed to generate data that would inform which rein and bit types were used in the following two studies.

2.1.2. Subjects

The study aimed to achieve a sufficient number of responses in order to generate accurate and reliable data. The survey was designed and distributed using Survey Monkey and was published to social media (Facebook) on a page aimed at communication between the equestrian population. From this 216 subjects responded. The survey was also distributed to the participants and subjects of the rein type study which generated a further 19 responses. The total subject population of n=235 was achieved.

Of the 235 respondents only six were male, i.e. 97.45% were female. Along with gender the specific age of the respondents were collected (mean ± SD = 31.368 ± 13.218 years of age) and divided into 6 categories (Table 1).

Table 1. Age of the Survey Respondents (n=234, respondent rate = 99.57%).

Age (Years)	**Percent (%)**
10 to 20	22.65
21 to 30	36.32
31 to 40	14.96
41 to 50	13.25
Over 50	12.82

Similar to the respondent's age the specific length of time the respondents have ridden for was supplied (mean ± SD = 23.119 ± 13.087 years) before being divided into 6 categories, see Table 2.

Table 2. Length of Time the Survey Respondents have Ridden For (n=235, respondent rate = 100%).

Ridden For (Years)	**Percent (%)**
Under 10	16.17
11 to 20	38.30
21 to 30	21.28
31 to 40	14.04
41 to 50	6.81
Over 50	3.40

2.1.3. Data Analysis

Once collected the raw data were collated into Microsoft Excel 2013. The respondents' answers were categorised for:

- Sex.
- Age (years).
- Ridden For (years).
- Participation in One or More Disciplines.
- Primary Discipline.
- Do you take part in Affiliated or Unaffiliated competitions?
- Primary Bridle Type.
- Reason for Primary Bridle Type.
- Primary Bit Type.
- Reason for Primary Bit Type.
- Primary Rein Type.
- Reason for Primary Rein Type.

Separation of the responses allowed the answers to be simplified, enabling similarities within the data to be easily and effectively identified. The raw data were sufficiently sorted within Microsoft Excel 2013 before being transferred into Minitab v18 software for statistical analysis. Frequency and percentage tests were performed in order to extract the respondents' age, sex, length of time ridden for, discipline and the most commonly used bridle, bit and rein types. Chi-squared analysis was conducted to determine the impact of the respondents' age, length of time the respondents' have ridden for, and primary discipline on the preference of the bit and rein types used.

2.2 Results

The respondents participation in one or more disciplines was calculated (Table 3) and highlighted the majority favoured only one discipline than compared to those that engaged in multiple disciplines.

Table 3. The Survey Respondents' Participation in One or More Disciplines (n=235, respondent rate = 100%).

Number of Disciplines	Percent (%)
>1	35.74
One	64.26

Of the primary disciplines favoured by the survey respondents Dressage was the most commonly engaged discipline, closely followed by Showing Jumping and then Leisure Riding (Happy Hacking). The remaining disciplines were only participated in by a minimal number of respondents.

Table 4. Primary Discipline Preferred by the Survey Respondents (n=235, respondent rate =100%).

Primary Discipline	Percent (%)
All Aspects	11.49
Dressage	27.23
Show Jumping	19.57
Eventing	10.21
Leisure Riding (Happy Hacking)	17.87
Showing	7.23
Racing	0.43
Endurance	0.85
Driving	0.85
Polo	1.28
Hunting	0.43
Riding Club	1.28
Retraining of Racehorses	0.43
Western	0.85

The respondents' participation in competitions were categorised into affiliated competitions (governed by an organisation, for example, a dressage competition regulated by British Dressage), unaffiliated competitions (not regulated), both, neither or no response (Figure 5). Participation in unaffiliated competitions was significantly greater than in comparison to the other three categories.

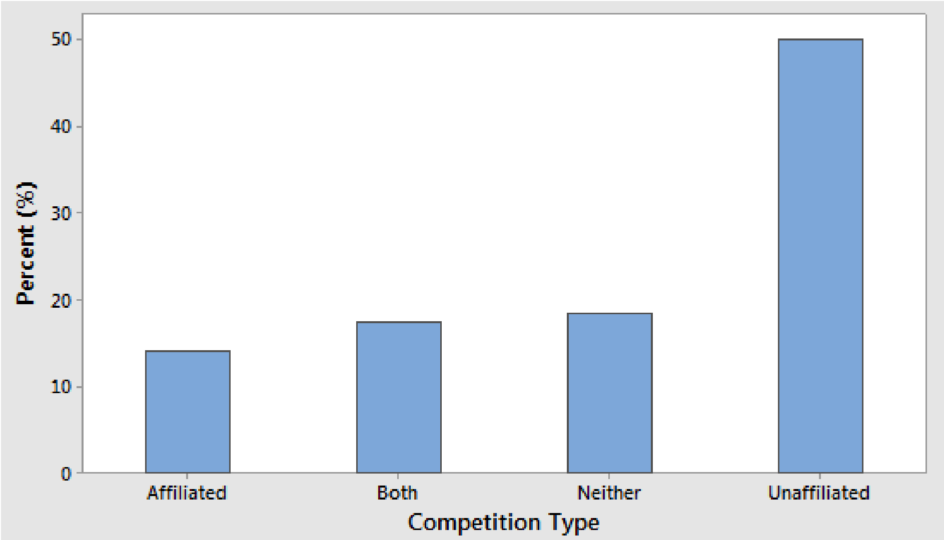

Figure 5. Survey Respondents' Participation in Affiliated and Unaffiliated Competitions. Values are percentages (n=234, respondent rate=99.57%).

Primary Bridle Type significantly preferred by the respondents was a standard bridle (simple leather bridle) followed by the Micklem™ bridle.

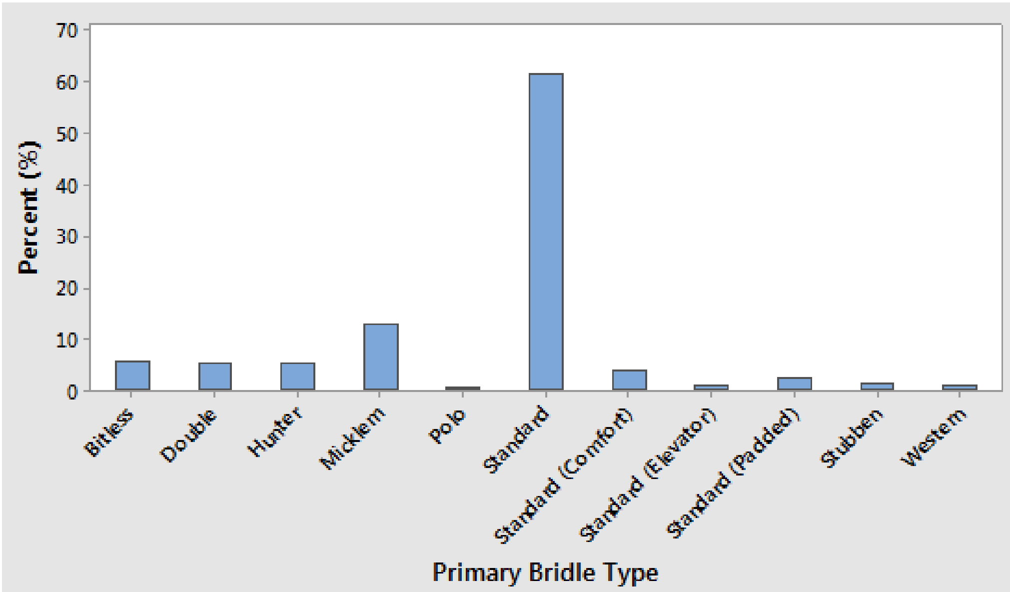

Figure 6. Survey Respondents Primary Bridle Type Preference. Values are percentages. (n=229, respondent rate=97.44%).

The majority of respondents provided No Response (Table 5) in relation to the reason behind Primary Bridle Type preference. Of the remaining sections the category of Suits horse in relation to Training and Performance received the highest number of responses.

Table 5. The Survey Respondents Reason for Primary Bridle Type (n=156, respondent rate = 66.38%).

Reason For Primary Bridle Type	Percent (%)
Competition Requirement	10.26
Suits horse in relation to Training and Performance	39.1
For Comfort (Including Simplicity)	26.28
For Relieving Pressure (Including Health Related)	10.27
For Control	14.1

Analysis of Primary Bit Type revealed the snaffle family of bits were significantly preferred than compared to any other bit type.

Table 6. The Survey Respondents Preference of Primary Bit Type (n=229, respondent rate = 97.44%).

Primary Bit Type	Percent (%)
Snaffle	84.71
Gag	4.37
Pelham	2.62
Bridoon	0.87
Kimblewick	0.87
Myler	1.31
Low Port Polo	0.47
Western	0.47
Not Applicable (Bitless)	4.37

Similar to the reasoning for Primary Bridle Type preference the category highlighted to be the most common reason for Primary Bit Type preference was No Response (Table 7). An interesting discovery was the third popular category being For Comfort (Including Bit Action and Simplicity); this may potentially correlate with the snaffle family of bits being the subtlest.

Table 7. The Survey Respondents Reason for Primary Bit Type (n=176, respondent rate = 74.89%).

Reason For Primary Bit Type	Percent (%)
Competition Requirement	10.23
Suits horse in relation to Training and Performance	28.41
For Training (Including Improving Performance)	12.5
For Comfort (Including For Bit Action and Simplicity)	21.59
For Control	20.45
For Relieving Pressure	3.98
Not Applicable (Bitless)	2.13

Rubber reins were revealed to be the most commonly favoured rein type (Table 8); followed with a substantial difference by leather and Half Leather Half Rubber.

Table8. The Survey Respondents Preference for Primary Rein Type (n=220, respondent rate = 93.61%).

Primary Rein Type	Percent (%)
Rubber	49.45
Thin Rubber	0.45
Bio Grip	3.18
Gel	0.45
Continental	5.45
Webbing	3.64
Eventer	3.18
Dressage (Including Double)	1.82
Half Rubber Half Leather	10.9
Laced Leather	3.63
Plaited Leather	3.64
Leather	11.36
Rope	1.82
Western Split or Rope	0.85

Unfortunately both the no response and personal preference (no specific reason supplied) received the highest counts of popularity for the reason behind Primary Rein Type preference (Figure 6). The category For Grip was the most popular response and may correlate with Rubber reins being the most commonly preferred rein type as they are renowned for grip.

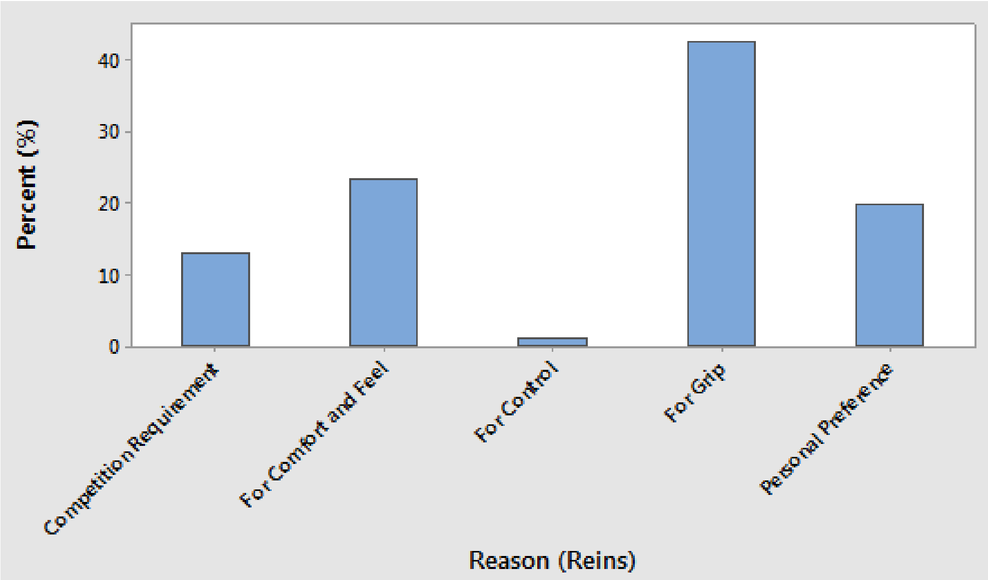

Figure 7 Survey Respondents Reason for Primary Rein Type. Values are percentages, n= 176, respondent rate = 74.89%.

Chi-squared analysis was conducted to determine the association between two variable combinations (Table 9). The results revealed that the age of the respondent significantly affected Primary Bit Type preference while Primary Discipline significantly impacted the reason behind Primary Bit Choice.

Table 9. Chi-Squared Analysis to determine associations between two variables.

Association between two variables	**Chi-Squared**	**P-Value**
Age*Primary Bit Type	24.7, DF=3	P<0.001
Age*Reason For Bit Type Choice	2.7, DF=4	P>0.001
Ridden For (Years)*Primary Bit Type	0.1, DF=1	P>0.001
Ridden For (Years)*Reason for Bit Type Choice	5.4, DF=5	P>0.001
Primary Discipline*Primary Bit Type	2.4, DF=1	P>0.001
Primary Discipline*Reason For Bit Type Choice	17.4, DF=8	P<0.05
Age*Primary Rein Type	2.7, DF=3	P>0.001
Age*Reason For Rein Type Choice	7.3, DF=3	P>0.001
Ridden For (Years)*Primary Rein Type	3.9, DF=2	P>0.001
Ridden For (Years)*Reason for Rein Type Choice	0.8. DF=3	P>0.001
Primary Discipline*Primary Rein Type	3, DF=4	P>0.001
Primary Discipline*Reason For Rein Type Choice	11.7, DF=6	P>0.001

2.3 Discussion

The survey generated two hundred and thirty-five responses; which could be considered to be a reasonable sample of the general practitioner section of the equestrian population; however it is less than one hundredth of one percent of the reported two and a half million riders within the UK (BETA, 2015). Therefore the survey results generated should be interpreted with caution. Although open-ended survey questions are a recognised methodology there are limitations with this type of qualitative research that require consideration (Hockenhull & Creighton. 2013; Hill *et al*., 2015). First, there is an inability to validate the data meaning the responses given must be taken at face value as reliable and accurate. Second, each respondent may not provide an answer for every question which will affect the sample size. A lack of answer was observed most commonly to the question of why the piece of equipment was used; which may be attributed to a paucity of knowledge from the respondent. Third, each respondent will interpret the questions differently and may not supply answers that are applicable to the survey, including providing false information as it is based upon retrospective self-report (Hill *et al*., 2015). This limitation may also provide a further explanation for the respondents' lack of response to specific questions. However Hockenhull & Creighton (2013) report that internet surveys are less affected by false information being provided than other survey types including face to face interviews as respondents may be influenced by what is believed to be socially acceptable and positive representation. In addition recruitment methods may inadvertently result in both an inaccurate representation of the population and a sample with biases through accumulating people with similar perceptions (Horseman *et al*., 2016). The survey was posted on social media and resulted in recruiting a 97.45% female response (two hundred and twenty-nine female respondents and six male) with 58.97% of the sample being under thirty years of age (22.65% between ten and twenty years old; 36.32% between twenty-one and thirty years old). Future work would benefit from distributing the survey to a sample with a range of diversity more representative of the population of equestrians. It should also be noted that although the age, gender and length of time the respondents have ridden for were consistently collected (only one no response for age); the level of experience of the respondent was left open to interpretation and resulted in difficulty for analysis and limited understanding of the population (Horseman *et al*., 2016). The question in future would benefit from being multiple choice with clear categorisations as the level of rider experience in theory would have a significant impact upon the items of tack chosen and used. Furthermore the remaining three survey questions were complex, implying three separate answers where to be provided regarding the type of tack and why it is used. This resulted in a range of answers that were difficult to interpret and analyse therefore the responses were categorised subjectively based upon the respondents' language and amount of detail provided which may have affected the accuracy and reliability (Hockenhull & Creighton, 2013). Future work would gain from re-working the question. For example, what types of reins do you use? Specify if you use different types for exercise, training and competition. Therefore the results generated by the study should be interpreted with caution because of these limitations.

According to the BETA survey (2015) 59% of the two and half million riders in the UK participate in unaffiliated competitions. Similarly the results of this survey revealed substantially greater participation in unaffiliated competitions than compared to affiliated competitions. This is an interesting finding as it further suggests the collected data are an accurate representation of the equestrian industry. The BETA survey (2015) highlighted a female sex bias (74%) within the equestrian population; which was further confirmed by this study as 97.45% were female. Along with these findings the majority of the responses originated from between the age of ten and thirty years old. This coincides with the BETA survey (2015) that the number of riders within the age range of sixteen to twenty-four years has significantly increased.

The survey revealed that the most commonly used bridle type was a standard bridle. The next bridle type was the Micklem™ which was then closely followed by the bitless bridle. Considering the wide range of tack that is available within the equestrian industry (Murray *et al*., 2015; Doherty *et al*., 2017) it is interesting to find that the majority of the population is still using simple standard equipment. Although the bitless bridle is not a factor within this study it is a finding worth further consideration as it appears to be increasing in popularity due to allowed use within some competitions (Waran, 2010). When analysing the reasoning behind the respondents' choice of bridle type the most popular reason was it suits the horse in relation to training and performance. Similar to the finding that the majority of the equestrian population are still implementing the continued use of standard simple equipment it was reassuring to find that the reasoning for this was that the equipment was chosen due to simplicity and horse preference. Therefore when evaluating these facts it may potentially be suggested that the welfare of the horse is considered when determining the use of different types of tack on the horse.

In relation to pressure being applied to the reins during ridden work the tension is impacted upon by a range of variables that include both rein type and bit type. Regarding rein type the questions were formed so as not to lead the respondent's answer. This however resulted in 14 different rein types being specified which does once again highlight the magnitude of the equipment available on the equestrian market (Randle *et al*., 2011; McGreevy *et al*., 2014; Doherty *et al*., 2017). However of these 14 rein types only 5 were required to be trialled within the next investigation. The first to be chosen were Rubber reins as these were shown to be the most common by the survey respondents (49.45%). The second rein type were plain leather, however as this encompasses Thick leather and Thin leather it was decided that both of these types would be trialled. The next rein type chosen were the Continental reins (5.45 %). The final rein type to be trialled was between the Laced leather and the Plaited leather reins as both received practically the same number of responses (3.63% and 3.64% respectively). It was concluded the Laced leather reins would be trialled as this type is more likely to be used across the majority of disciplines than compared to the plaited leather reins that are mainly required for showing. During statistical analysis of the reason behind the respondents' choice of rein type it was discovered that For Grip was the most popular answer. This was not a surprising outcome and may potentially coincide with the fact that rubber reins are renowned for grip. Similar to For Grip the next category in order of popularity was For Comfort and Feel. It is an interesting finding that of the four categories the two revealed to have the highest popularity where related to how the reins actually feel in the rider's hand rather than how the piece of equipment may impact the ridden horse. Therefore raising important welfare questions regarding which rein type is actually the most suitable to the horse in relation to applied rein tension.

The two remaining questions of the survey aimed to determine the bit type preferences and reasoning behind the choice of the equestrian population. Although 8 different bit type families were specified, only one family was significantly favoured. The Snaffle family of bits were revealed to be the most commonly used type (84.71%) by the equestrian population and the family of bits that would be trialled during the third investigation. It should be noted that this result may be due to the biases found within the sample size and demographic. The next bit type of choice in order of preference was the Gag with minimal responses (4.37 %). In contrast with the same number of counts was the Bitless bridle. The remaining specified bit families are used in relation to strong horses due to being greater in severity (Randle & Wright, 2013; Vanderhost *et al*., 2013) and only received minimal counts. In comparison to the respondents reasoning for bridle type choice it was interesting to discover that the main reason for bit type choice was also it suits horse in relation to training and performance. Therefore further suggesting that the welfare of the horse is foremost for the majority of the equestrian population as equipment is being implemented and only continually used by the preference of the horse. This assumption is further confirmed by the second category favoured by the survey respondents for comfort (including for bit action and simplicity) as it implies that standard simple equipment is still being favoured.

The chi-squared analysis revealed two significant associations; the relationship between the respondents age and the choice of primary bit type and the respondents primary discipline on the reason for the choice of primary bit type. However these results should be taken with caution as the later combination was marginally significant ($P<0.05$) while the first combination was reliably more significant ($P<0.001$). The lack of significant values of this chi-squared analysis highlighted that limited conclusions can be drawn from these results. Therefore future work would benefit from firstly a larger and more diverse population size. Second, to include questions that aim to determine the respondents' level of knowledge and experience to investigate whether this rather than age or length of time the respondent has ridden for is the variable that is effecting tack choices. The impact of the respondents' sex was not analysed due to the considerable difference between the number of female and male respondents, with the bias being significantly in the females favour (two hundred and twenty-nine female responses and only six male responses). Although statistical analysis to an extend can cope future work that aims to determine the impact of respondent sex on tack choices may benefit from a sample of the population that is considerably more even between the number of female and male responses.

2.4 Conclusion

The aim of the survey was to determine which rein and bit types would be trialled in the following two studies by analysing and identifying which are the types favoured by the equestrian population. The results revealed for the second study, the effect of rein type on rein tension in the ridden horse, rubber, continental, laced leather, thick leather and thin leather reins would be trialled. While, in the third study, the effect of bit type on rein tension in the ridden horse it was concluded that bit types which originate from the snaffle family would be investigated.

Although the survey sample demographics and size suffered from biases as a direct result of the data collection method and the information produced should be taken with caution; the study revealed the use of standard simple equipment to be the most popular for reasons including horse preference in relation to both training and performance. This finding was neither predicted nor expected due to the range of equipment that is currently readily available within the equestrian industry. However the finding may potentially suggest that the welfare of the horse is considered by the equestrian population when deciding the implementation of different types of tack on the horse.

3. The Effect of Rein Type on Rein Tension in the Ridden Horse

The main objective of this quantitative study was to build on the preliminary study conducted by Randle *et al*. (2011) by comparing the effect of five rein types on rein tension through identification of which rein type maintained the least and most consistent tension. The study aimed to compare the effect of different rein types on rein tension and facilitate comparisons across different studies with the interest of benefiting the welfare of the ridden horse.

3.1 Methods and Materials

3.1.1. Subjects (Riders)

Nine riders, eight female and one male (Age: 40.563 ± 15.876years) were used (Table 10). The study continues along the main theme of the qualitative survey to investigate the types of tack used by the general practitioner within the equestrian industry. Therefore the riders used within the study were all leisure riders that participated in local competitions and were sufficiently able to walk, trot and canter within an arena.

Table 10. Demographic of each Rider used in the Rein Type Study.

Rider	Age (Years)	Sex	Ridden For (Years)
1	63	Female	60
2	24	Male	8
3	53	Female	40
4	48	Female	3
5	63	Female	53
6	60	Female	50
7	48	Female	38
8	49	Female	4
9	22	Female	20

3.1.2. Subjects (Horses)

Thirteen horses, six mares and nine geldings of varying breeds (Height: 15.488 ± 0.694hh; Age: 12.719 ± 4.143 years) were used (Table 11).

Table 11. Demographic of each Horse used in the Rein Type Study.

Horse	Age (Years)	Breed	Sex	Height (hh)
1	9	Dutch Warmblood	Gelding	17
2	8	Irish Draught	Gelding	16.2
3	17	Irish Sports Horse X Andalusian	Mare	16.1
4	13	Argentine Polo Pony	Mare	15.2
5	17	Argentine Polo Pony	Gelding	15.1
6	17	Argentine Polo Pony	Mare	14.2
7	10	Warmblood X	Gelding	16.1
8	9	Lusitano	Mare	15
9	9	Lusitano	Mare	15
10	22	Hackney X Welsh Cob	Gelding	15.2
11	17	Argentine Polo Pony	Gelding	15.1
12	11	Irish Draught X Welsh D	Gelding	16.1
13	10	Warmblood X	Gelding	16.1
14	9	Lusitano	Mare	15
15	11	Welsh D	Gelding	15.2

Legend: X = Crossed with.

3.1.3. Environment

The data collection sessions took place at Apsley End, Model Farm, Hanscombe End Road, Shillington, Hertfordshire, SG5 3NA between the 11th and 12th of August 2016. The outdoor arena used was 60m x 20m with a sand and carpet mixture surface and fenced with wooden boarding at a height of approximately 1.80m. The arena used was outside the wooden boarding thus preventing external factors including other horses, passers-by, houses, and traffic from influencing either the horse or the sessions; therefore increasing the reliability of the collected data. The sessions occurred across two days between the hours of 10.00am and 6.00pm during the summertime, the weather was warm and calm with minimal winds. Therefore the weather conditions had no effect on the data collected (Pinchbeck *et al.*, 2004) as local factors including temperature and humidity have previously been shown to effect rein tension devices.

3.1.4 Riding Equipment

The fifteen horses that participated wore their normal correctly fitted tack (see Appendix 2) for riding on the flat. No martingales were worn by any horse as they have been shown to influence rein tension (Heleski *et al*., 2009; Randle & O'Neill, 2015).

The type of reins chosen for ridden work are dependent on the intended usage (Batty-Smith e.d, 2008, pp. 227). For instance, leather reins including, plain, laced, plaited and half leather half rubber tend to be used for eventing; whereas other reins types such as webbing and nylon are more commonly used for jumping (Batty-Smith e.d, 2008, pp. 227). A variety of rein types have leather slots sown on every 13-15cm or notches to enable a more secure grip. For safety of the horse and rider it is essential that the reins have a buckle or fastening at the middle especially in materials that do not break easily. The most common sized reins are as follows:

- 1.5m (Full length).
- 1.4m (Used for Show-Jumping and Flat Racing).
- 1.3m (Pony Reins).

For the study five rein types were trialled (Table 12 and Figure 8):

Table 12. The Five Rein Types Trialled in the Rein Type Study.

Reins	**Material**	**Dimensions (mm)**	**Length (m)**	**Weight (g)**
Rubber	Rubber	Width = 18 Depth = 6	1.38	280
Continental	Web	Width = 16 Depth = 3	1.46	200
Thin Leather	Leather	Width = 12 Depth = 3	1.46	161
Thick Leather	Leather	Width = 15 Depth = 4	1.38	208
Laced Leather	Leather	Width = 20 Depth = 6	1.46	267

Rubber

Continental

Laced Leather

Thick Leather

Thin Leather

Figure 8. The Five Rein Types Trialled in the Rein Type Study (pictures taken by the author).

3.1.5. Rein Tension Gauge

The Centaur Rein Tension Device Professional edition S2013 (Centaur Trainology BV, PO Box 1034, 5200 BC ‘s-Hertogenbosch, The Netherlands) are calibrated to measure tension in Newton’s (N) and have a capacity of 0 to 200N. The gauges have a 125% overload capability that equates with 250N, if tension above this threshold is applied it may compromise accuracy. The gauges were calibrated (technology is self-calibrating) before each data collection and were inserted between the reins and bit (Figure 9) of the bridle (Oakes, 2014) on both sides of the horse with each sensor weighing approximately 35g (Steenbergen, 2014, pp. 9); they are connected via a short cable to the data logger which is attached using Velcro straps to either the back of the noseband or throat lash depending on whether a noseband was present.

Figure 9. The Rein Tension Device (picture taken by the author)

During the ridden stage the rider maintained what was perceived to be a normal ‘contact’ and performed exercises in the three lower gaits of walk, trot and canter (Cross *et al*., 2017); the data collected represents the tension transmitted along the reins with a sensitivity accuracy of up to 10g. The gauges record the data and it is then transmitted via Bluetooth to a receiver connected to a USB port on a laptop. The gauges are able to transmit the data from a distance of up to 40m from the laptop with a transfer rate of 100 samples per second (100Hz). During the sessions the data were transferred to the accompanying Centaur computer software (Centaur.GUI) and shown in real-time on the laptop (Figure 10) through a series of readings that differed in frequency and magnitude (Clayton *et al*., 2003).

Figure 10. Rein Tension Data in Real-Time on the Centaur. GUI Computer Software (screenshot of authors' laptop during analysis).

The graph consists of a vertical axis representing the tension in Newton's (N) while the horizontal axis corresponds to the time in seconds (s). 10N is the equivalent of 1 kilogram of pressure (1kgF) applied to the reins whether it originates from the horse or rider and shows the minimum and maximum tensions and the difference between the left and right hands of the rider (Leemans *et al*., 2016). It is essential that the gauges are attached to the correct rein as tension is shown through two lines on the graph; the red line represents the right rein while the green line corresponds with the left rein. Each step taken by the horse and rider correlates with the spikes shown on the graph.

3.1.6. Testing Protocol

The following unifying hypotheses were tested:

The null hypothesis (H_o): there is no significant impact on rein tension by rein type.

The alternative hypothesis (H_a): there is a significant impact on rein tension by rein type.

During the data collection sessions the following steps where undertaken and repeated for each individual horse and rider dyad trialled:

1. The horse and the rider entered the arena and commenced a normal warm-up of 5 to 10 minutes in length.

2. The rein tension gauges were calibrated and safely attached to the rein and bit of the bridle.
3. Test one was carried out by the horse and rider which involved completing a specific route around the arena in the first three gaits on both rein directions using either their normal rein type or an alternative rein type (see Appendix 3 and 4).
4. Once completed the rein type was changed and test two commenced. The horse and rider where again asked to complete a specific route around the arena with either their normal rein type or an alternative rein type (see Appendix 3 and 4).
5. The rein tension gauges were safely removed before the horse and rider exited the arena.

The rein type trialled by the horse and rider during test one and test two where determined according to the random crossover design (see Appendix 3). Test one commenced with the horse and riders normal rein type staying in place or an alternative rein type being correctly fitted and trialled; test two then began immediately after test one was completed. Test two trialled the opposite variation than compared to test one, either the normal reins used by the horse and rider where re-fitted or an alternative rein type was fitted and trialled.

The specific route around the arena completed by the horse and rider during each test was determined according to the random crossover design (see Appendix 4). The routes differed in which rein direction the trial began on and which order the gaits where completed in.

3.1.7. Data Analysis

Although the recorded rein tension data were displayed graphically (Figure 10) in the Centaur Rein Tension (Centaur.GUI) accompanying computer software it was not a sufficiently reliable or accurate method in which to analyse the extensive volume of data. Therefore the data were exported into Microsoft Excel 2013. However as the data would be analysed in Minitab v18 statistical software it was simpler to organise it within that programme. The data were sorted into sets to identity particular variables resulting from both the horse and the rider. These included left rein hand, right rein hand, left rein direction, right rein direction, gait, and rein type. The dependent variable was the rein tension while the independent variables were categorised into Rein Hand, Gait, Rein Direction, Rein Type, Horse Breed, Horse Age (Years), Horse Sex, Horse Height (hh), Rider Age (Years), Rider Sex and Ridden For (Years). For statistical analysis the factorial AnOVa (analysis of variance) test was used (Petrie & Watson, 2006, pp. 97-106) with the level of significance set at $p<0.001$. The minimal, maximal and mean rein tensions were extracted to give an overall rounding evaluation of the rein tension. A Post-hoc Tukey's test was performed to determine which levels of each variable were significantly different.

3.2 Results

There was a significant effect of rein type on rein tension (One-way Analysis of Variance: $F_{4,1060}=20.13$; $P<0.001$; Figure 11). Rein tension was highest for Rubber (12.928±0.377N; Minimum: 4.750N; Maximum: 29.405N) and Continental reins (12.399±0.54N; Minimum: 1.317N; Maximum: 66.306N) and lowest for Laced (9.730±0.377N; Minimum: 2.291N; Maximum: 23.756N), Thick (9.618±0.368N; Minimum: 1.962N; Maximum: 24.233N) and Thin (9.157±0.352N; Minimum: 5.146N; Maximum: 24.06N) Leather reins. These two groups, Rubber and Continental reins and laced, Thick and Thin Leather Reins (shown as A and B in Figure 11) differed significantly (Tukey's test details in caption of Figure 11 and Appendix 5).

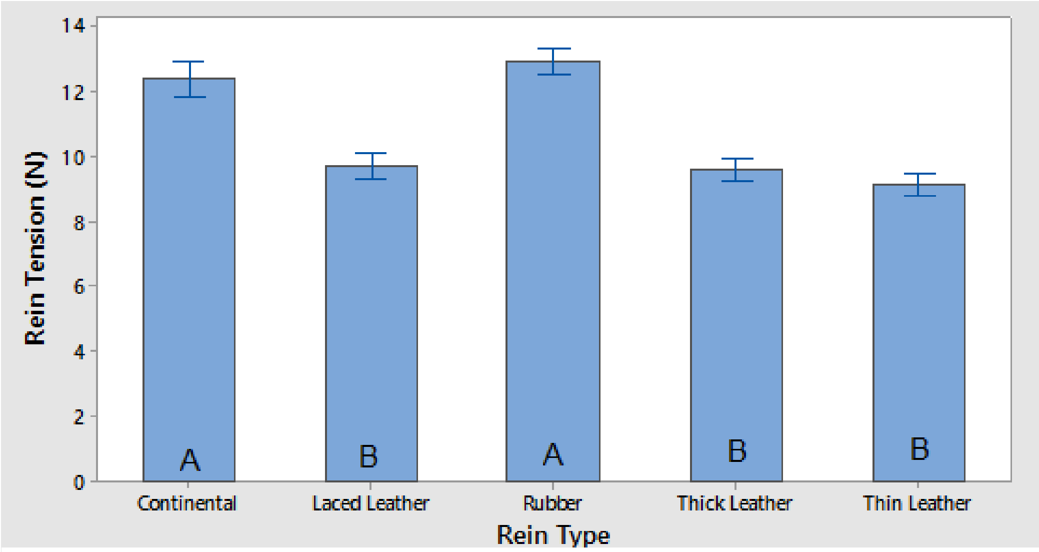

Figure 11. The effect of Rein Type on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 3.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between rein types (Tukey's T absolute values: 4.76 – 6.8. P<0.001); same letters indicate no significant difference between rein type (Tukey's T absolute values: 0.22 – 1.08. P = 0.875 – 0.999); full details in Appendix 5.

Rein tension was significantly impacted upon by gait (One-way Analysis of Variance: $F_{2,1060}=53.21$; $P<0.001$; Figure 12). Rein tension was lowest for Walk (8.968±0.243N; Minimum: 1.383N; Maximum: 23.409N), followed by Trot (10.065±0.316N; Minimum: 1.192N; Maximum: 66.306N) and highest for Canter (13.223±0.364N; Minimum: 1.317N; Maximum: 37.482N). These three gaits differed significantly from each other (Tukey's test details in caption of Figure 12 and Appendix 6).

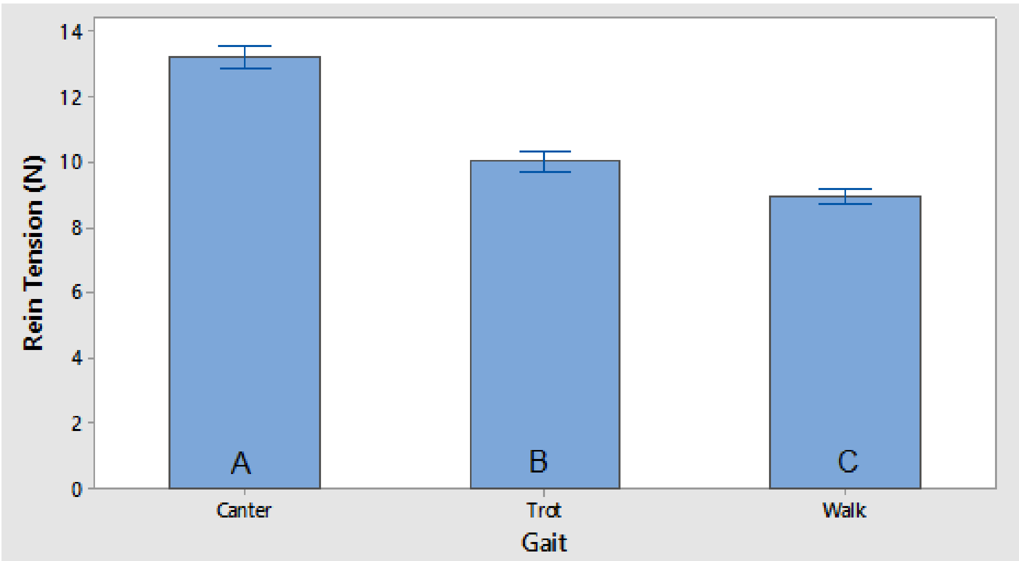

Figure 12. The effect of Gait on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 3.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between the gaits (Tukey's T absolute values: 2.54 – 9.85; P<0.05); full details in Appendix 6.

Rein tension was not significantly affected by either the rein direction (One-way Analysis of Variance: $F_{1,1060}$=3.13; P>0.05; Left Rein Direction: 10.456±0.25N; Minimum: 1.192N; Maximum: 30.196N; Right Rein Direction: 11.063±0.28N; Minimum: 1.586N; Maximum: 66.306N; Figure 13) or the rider's rein hand (One-way Analysis of Variance: $F_{1,1060}$=0.18; P>0.05; Left Rein Hand: 10.684±0.27N; Minimum: 1.192N; Maximum: 66.306N; Right Rein Direction: 10.835±0.263N; Minimum: 1.931N; Maximum: 37.482N; Figure 14). The Tukey's test confirmed no significant difference between either rein hand or rein direction (Tukey's test in caption details in Figure 13 and 14 and Appendix 7 and 8).

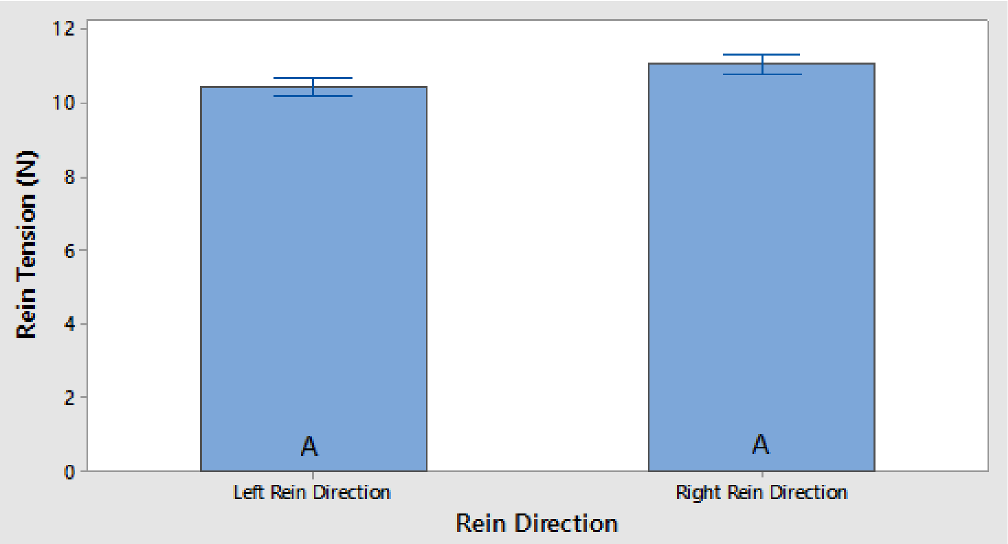

Figure 13. The effect of Rein Direction on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 3.1 for sample size. Letters refer to Tukey's Post-hoc test, same letters indicate there is no significant difference between rein directions (Tukey's T absolute value: 1.76; P>0.05); full details in Appendix. 7.

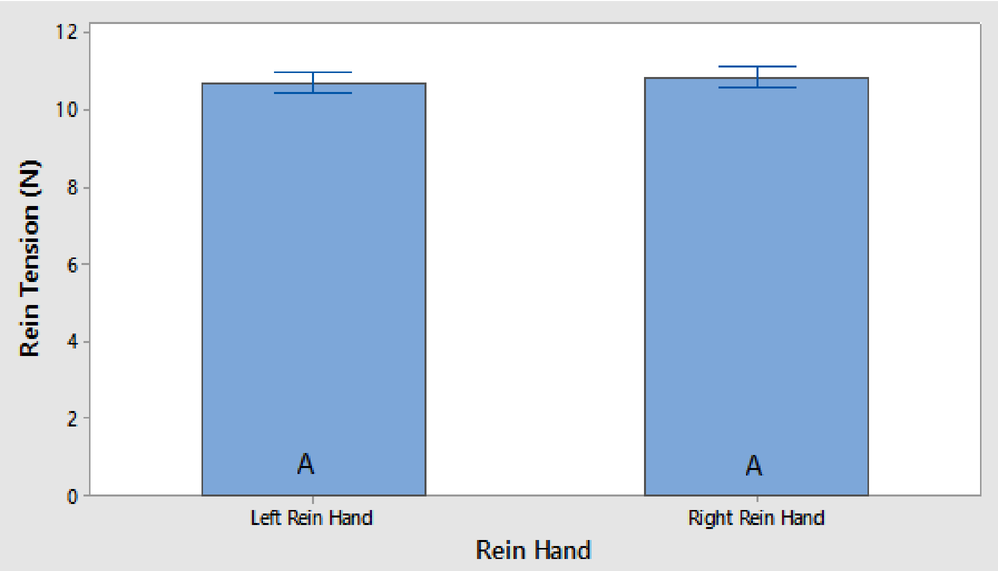

Figure 14. The effect of Rein Hand on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 3.1 for sample size. Letters refer to Tukey's Post-hoc test, same letters indicate there is no significant difference between rein hands (Tukey's T absolute value: 0.43; P>0.05); full details in Appendix 8.

Rein Type and Gait had a significant effect on rein tension (Two-way Analysis of Variance: $F_{8,1060}$=2.69; P<0.001; Table 13).

Table 13. The effect of Rein Type and Gait on Rein Tension (N). See Methods and Materials section 3.1 for sample size.

Rein Type	**Gait**	**Mean ± SE(N)**	**Minimum (N)**	**Maximum (N)**
Continental	Walk	10.608±0.709	1.672	23.409
	Trot	12.74±1.04	2.15	66.31
	Canter	13.745±0.971	1.317	17.576
Rubber	Walk	10.111±0.351	5.947	17.643
	Trot	11.362±0.507	4.750	28.095
	Canter	17.246±0.7	6.267	29.405
Laced Leather	Walk	8.694±0.592	2.431	22.458
	Trot	8.796±0.583	2.291	23.356
	Canter	11.758±0.722	2.383	23.756
Thick Leather	Walk	7.514±0.355	3.033	15.816
	Trot	8.804±0.539	2.745	18.833
	Canter	12.535±0.789	1.962	24.233
Thin Leather	Walk	7.976±0.565	1.383	19.008
	Trot	8.673±0.576	1.192	18.938
	Canter	10.790±0.641	2.342	24.060

Rein tension was significantly affected by Horse Age (One-way Analysis of Variance: $F_{6,1062}$=72.99; P<0.001; Table 14), Horse Sex (One-way Analysis of Variance: $F_{1,1067}$=3.93; P<0.001; Table 15) and Horse Breed (One-way Analysis of Variance: $F_{8,1060}$=99.06; P<0.001; Table 16).

Table 14. The effect of Horse Age on Rein Tension (N). See Methods and Materials section 3.1 for sample size.

Horse Age	**Mean ± SE(N)**
8	15.980±0.587
9	14.131±0.356
10	11.220±0.335
11	11.488±0.638
13	3.476±0.077
17	7.899±0.273
22	8.434±0.216

Table 15. The effect of Horse Sex on Rein Tension (N). See Methods and Materials section 3.1 for sample size.

Horse Sex	**Mean ± SE(N)**
Mare	10.303±0.334
Gelding	11.064±0.22

Table 16. The effect of Horse Breed on Rein Tension (N). See Methods and Materials section 3.1 for sample size.

Horse Breed	**Mean ± SE(N)**
Argentine Polo Pony	5.990±0.235
Dutch Warmblood	12.617±0.693
Hackney X Welsh Cob	8.434±0.216
Irish Draught	15.980±0.587
Irish Draught X Welsh D	5.752±0.243
Irish Sports Horse X Andalusian	11.006±0.5
Lustiano	14.792±0.405
Warmblood X	1.220±0.335
Welsh D	17.389±0.792

Legend: X = crossed with

Rein tension was significantly affected by Rider Age (One-way Analysis of Variance: $F_{6,1062}$=120.60; P<0.001; Table 17), Rider Gender (One-way Analysis of Variance: $F_{1,1067}$=225.68; P<0.001; Table 18) and Length of time of the Rider has Ridden For (One-way Analysis of Variance: $F_{8,1060}$=102.37; P<0.001; Table 19).

Table 17. The effect of Rider Age on Rein Tension (N). See Methods and Materials section 5.1 for sample size.

Rider Age	**Mean ± SE(N)**
22	9.834±0.827
24	13.937±0.267
48	5.694±0.265
49	5.752±0.243
53	5.751±0.292
60	17.207±0.308
63	11.169±0.435

Table 18. The effect of Rider Gender on Rein Tension (N). See Methods and Materials section 5.1 for sample size.

Rider Gender	**Mean ± SE(N)**
Female	8.678±0.223
Male	13.937±0.267

Table 19. The effect of Ridden For (Years) on Rein Tension (N). See Methods and Materials section 5.1 for sample size.

Ridden For (Years)	Mean ± SE(N)
3	2.875±0.12
4	5.752±0.243
8	13.937±0.267
20	9.834±0.827
38	8.434±0.216
40	5.751±0.292
50	17.201±0.308
53	10.171±0.504
60	12.617±0.693

3.3 Discussion

The results reported a significant impact on rein tension by rein type. The rein types increased in level of tension maintained from Thin leather, Thick leather, Laced leather, Continental to Rubber. However the Post-hoc Tukey's highlighted there to be no significant difference between Thin, Thick and Laced Leather reins and no difference between Continental and Rubber reins. Although tension was highest for the Rubber reins it was in fact more consistent than the Continental reins which were second highest in terms of tension. Following this the level of tension decreases while the consistency increases in the remaining rein types. Randle *et al.* (2011) research used different rein types, but the results revealed Thin leather reins to also maintain the least degree of pressure; therefore further confirming reliability of this study. When evaluating these results in conjunction with the data produced by the Survey study it highlights that the rein type to maintain the highest level of tension was also the rein type most commonly favoured by the equestrian population. This is an interesting finding which requires further research to determine the potential effect and degree of impact on the training and welfare of the ridden horse (Cross *et al*., 2017).

Clayton *et al.* (2011) discuss the intricate relationship between each of the variables that affect applied rein tension and therefore it can be difficult to determine the effect of a single variable. Therefore to compensate for this difficulty it is recommended that the mean and standard deviation or standard error is reported for multiple comparisons of the variables to produce a greater level of analysis and understanding. Also, Eiseriö *et* *al.* (2015) report that rein tension data would benefit from being characterised according to variables that are relatable. For instance the study reported a significant connection between the magnitude and consistency of rein tension and gait (walk<trot<canter). Similar results were described by Clayton *et al.* (2003) and Kuhnke *et al*. (2010) and from this current research. During single variable analysis both the riders rein hand and the rein direction were shown to have no significant effect on rein tension. Symmetry is an essential and important finding to report as it is an objective of each individual rider and also aligns with previous studies by Warren-Smith *et al.* (2007) and Clayton *et al.* (2011).

Eiseriö *et al*. (2015) suggest that when conducting rein tension research it is valuable to evaluate both the horse's physical and psychological reaction to the pressure applied. However this cannot be reliably evaluated solely using rein tension data as the device simply measures the tension between the bit and the rider's hand only; this results in difficulty determining whether the pressure was applied by the horse or the rider or both. According to Hawson *et al*. (2014) previous studies have aimed to overcome this problem. In 2011 Clayton *et al.* proved that the peaks and troughs seen during rein tension data have occurred due to changes in the horse's head position which corresponds with the gait and stride of movement (Clayton & Hobbs, 2017). While, Egenvall *et al*. (2015) concluded which percentage of the recorded tension can be attributed to the horse and the rider. However it is difficult to determine when exactly how the applied pressure is distributed across the horse's mouth by the bit is still undetermined (Eiseriö *et al*., 2015). Therefore when conducting further research into rein tension it is recommended the behaviours exhibited by the horse throughout data collection be recorded and evaluated using an ethogram against the rein tension data. In conjunction, analysis of the rider's biomechanics would enable analysis of the connection between the exhibited behaviours and rein tension along with pressure from the rider's legs and seat; i.e. is the rider implementing an independent seat (Christensen *et al*., 2011; Hall & Heleski, 2017). Future studies implementing these types of data collection have the potential to determine the point at which applied pressure becomes aversive for the ridden horse and whether it is pressure itself or confusion of the aids. Therefore potentially leading to methods that aid and reinforce the horse in exhibiting the correct response (Egenvall *et al.,* 2012) and in turn to minimisation of behaviours that are indicative of conflict and improvements in ridden horse welfare.

Cook and Mills (2009) suggest that performance in the first test does not affect the second. However Cook and Mills (2009) go on to explain it as implausible for a number of reasons and is a limitation of this research that requires consideration. First, there is the possibility of an order effect. A change in the horse's behaviour may be seen due to the horses being warmed-up for the second test rather than the change in condition that is being trialled. Or the change in behaviour may be attributed to familiarity of the test situation than the change in condition. Second, fatigue. The change in behaviour may be exhibited as the horse tires however it is unlikely as fatigue corresponds with an increase in errors (Cook & Mills, 2009). During experimental design the aim was to have each horse and rider complete the first test followed by an hour break (i.e. washout period) before completing the second test to remove the likelihood of both order effect and fatigue. However Pierard *et al*. (2015) suggest two methodologies that can be employed to control for this limitation where the horse and rider are not at a baseline condition for the second test; either increase the sample size to remove the issue or use a cross-over design to compensate. Due to the constraints resulting from the rider and horse participants' availability for the washout period time frame or an increase in sample size was not viable. Therefore the tests were determined randomly using a cross-over design (Pierard *et al*., 2015) with an aim to minimise the impact of order effect, familiarity and fatigue. Although it can be concluded that due to the methodology the results of this study are reliable, future work would benefit from a larger sample size to validate reliability and accuracy of results produced.

3.4 Conclusion

Statistical analysis of the data collected revealed that rein type had a significant effect on rein tension in the ridden horse; with thin leather reins maintaining the least and most consistent level of applied tension while Rubber and Continental maintained the highest. A finding of the study worth further consideration is the rein type (rubber reins) shown by the Survey to be the most commonly used by the equestrian population being the rein type that maintains the highest level of tension. However this investigation is classified as preliminary research and therefore highlights the essential requirement for further research to be conducted into this area with a much greater sample size to determine the effects of rein type in relation to training, performance and the welfare of the ridden horse.

4. The Effect of Bit Type on Rein Tension in the Ridden Horse

There is an abundance of bit varieties on the equestrian market that are used from every day to training to competitions (McGreevy *et al*., 2014); along with those used for overcoming both training and performance problems. The Snaffle family of bits are the most commonly used type within the equestrian industry (Hill *et al*., 2015; Doherty *et al*., 2017) as confirmed by the results of The Survey (section 2). Currently there is a wide range of research into bit type in relation to rein tension however there is a paucity of baseline data within the literature. The main purpose of the investigation was to collect objective rein tension data to describe and compare the effect of different bit types on rein tension and facilitate comparisons across different studies with the interest of benefiting the welfare of the ridden horse.

4.1 Methods and Materials

4.1.1. Subjects (Horses)

Twenty-nine horses, sixteen mares and thirteen geldings of varying breeds (Height: 15.335 ± 0.863hh; Age: 11.814 ± 4.421years) were used (Table 20).

Table 20. Demographic of the Horses Trialled in the Bit Type Study.

Horse	Age (Years)	Breed	Sex	Height (hh)
1	15	Warmblood X TB	Mare	16
2	23	Welsh X Arab	Mare	14.2
3	6	Cob	Mare	14.3
4	15	TB	Gelding	16.2
5	13	Andalusian	Gelding	14.1
6	8	British Riding Pony	Mare	14.2

7	7	Sports Horse	Gelding	15.2
8	18	Unknown	Mare	14.1
9	8	Irish Sports Horse	Gelding	15.1
10	12	New Forest X Arab	Mare	14.2
11	7	Warmblood	Mare	16.2
12	12	Warmblood (KWPN)	Mare	16.3
13	10	Unknown	Gelding	15
14	10	Unknown	Mare	15.2
15	10	Cob	Mare	14
16	6	Warmblood	Mare	16.2
17	9	Cob X	Mare	15.1
18	9	Dutch Warmblood	Gelding	17
19	8	Irish Draught	Gelding	16.2
20	17	Irish Sports Horse X Andalusian	Mare	16.1
21	13	Argentine Polo Pony	Mare	15.2
22	17	Argentine Polo Pony	Gelding	15.1
23	17	Argentine Polo Pony	Mare	14.2
24	10	Warmblood X	Gelding	16.1
25	10	Warmblood X	Gelding	16.1
26	22	Hackney X Welsh Cob	Gelding	15.2
27	11	Irish Draught X Welsh D	Gelding	16.1
28	10	Warmblood X	Gelding	16.1
29	9	Lustiano	Mare	15

Legend: X=Crossed With

4.1.2. Subjects (Riders)

Eleven riders, ten female and one male (Age: 33.788 ± 14.905 years) were used (Table 21).

Table 21. Demographic of the Riders Trialled in the Bit Type Study.

Rider	Age (Years)	Sex	Ridden For (Years)
1	22	Female	20
2	26	Female	15
3	23	Female	12
4	63	Female	60
5	24	Male	8
6	53	Female	40
7	48	Female	3
8	63	Female	53
9	48	Female	38
10	49	Female	4
11	22	Female	20

4.1.3. Environment

The data collection sessions took place at Duchy College, Bicton College and Barons Wood, Bow, EX17 6LQ between April 4th and May 31st 2017. The two indoor and one outdoor arenas used were 60m x 20m with a sand and carpet mixture surface. Although one arena used was outside the secluded location, wooden fencing and earth banks prevented external factors including other horses, passers-by, houses, and traffic from influencing either the horse or the sessions; therefore increasing the reliability of the collected data. The sessions occurred between the hours of 10.00am and 6.00pm across multiple locations on days where the weather was warm and calm with minimal winds.

4.1.4. Riding Equipment

All twenty-nine horses used wore their normal correctly fitted saddles, bridles and bit types (see Appendix 9) for riding on the flat. Each of the horses wore the same set of thin leather reins to remove one of the variables as this rein type was shown to maintain the lowest and most consistent rein tension. No martingales were worn by any horse as they have been shown to influence rein tension (Heleski *et al*., 2009; Randle & O'Neill, 2015).

McGreevy *et al*. (2014) explain that along with bit type the dimensions including size, width and length will influence how the applied rein tension is transferred and dispersed throughout the horse's mouth. Therefore it is essential when executing equitation research that the bit is correctly fitted and the dimensions and type used are specified.

All the bit types' trialled were snaffle bits (Table 18). These types of bit act on the tongue, bars, sides of the bars, lips and corners of the mouth (Tuke, 1965, pp. 31) and give the horses the clearest of signals (Vernon, 1998, pp. 38). The Snaffle bits trialled in this study were a mixture of Eggbutt, Loose-Ring, Full-Cheek and Hanging-Cheek with the mouthpieces consisting of either a Mullen Mouth, Single-Joint or Double Joint.

Eggbutt: The fixed ring minimises the likelihood of the bit either rubbing or pinching the horse's lips. It inhibits the bit from being pulled through the horse's mouth by keeping it evenly situated in the oral cavity (Tuke, 1965, pp. 32) and has a more defined action when distributing pressure signals than compared to other bit types.

Figure 15. An Eggbutt Ring Snaffle (picture taken by the author).

Loose-Ring: The freeness of the ring reduces pinching by creating freer movement of the mouthpiece; encouraging the horse to chew on the bit. When the rider picks up the rein the mouthpiece slides onto the cheek before the horse feels the pressure.

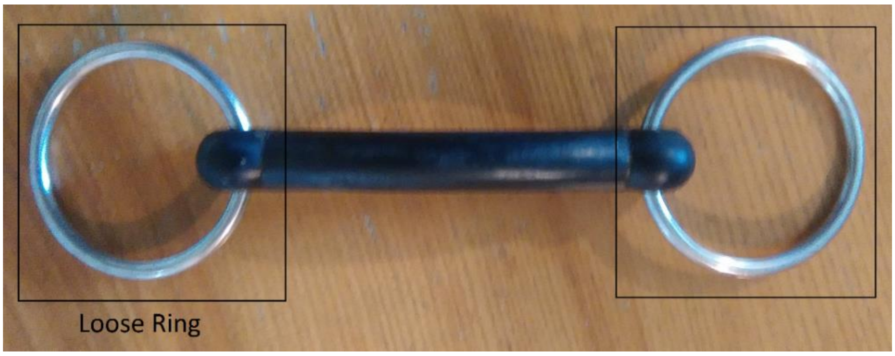

Figure 2. A Loose-Ring Snaffle (picture taken by the author).

Full-Cheek: It is a quiet bit renowned for being used on young horses as the cheek distributes the pressure on the side of the horse's face encouraging turning while also promoting straightness of the face (Vernon, 1998, pp. 40).

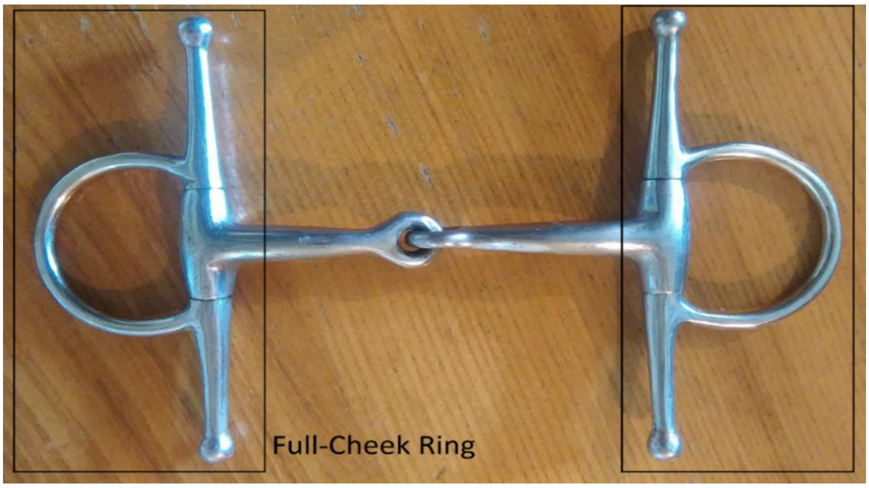

Figure 3. A Full-Cheek Snaffle (picture taken by the author).

Hanging Cheek: This bit type creates poll pressure (Vernon, 1998, pp. 38) by suspending the bit within the horse's oral cavity. It enables a larger area for the horse's tongue and is beneficial for horse's that place the tongue over the bit (Batty-Smith, 2008, pp. 247).

Figure 4. A Hanging-Cheek Snaffle (picture taken by the author).

Happy Mouth: The bit distributes applied pressure across the bars of the horse's mouth and the lips. However as it is difficult to use the reins independently; increased pressure on one rein results in the bit being pushed forward on the opposite side.

Figure 19. A Happy Mouth Snaffle (picture taken by the author).

Single-Jointed: The one joint enables a greater degree of movement within the horse's mouth. If the bit is fitted correctly it disperses the applied pressure on the bars of the mouth and lips. However when fitted incorrectly the joint closes and creates pressure on the roof of the mouth or the tongue. When the rider lifts the hands it creates more pressure on the lips whereas in comparison lowered hands disperse a greater degree of pressure onto the bars of the mouth, the roof and the tongue.

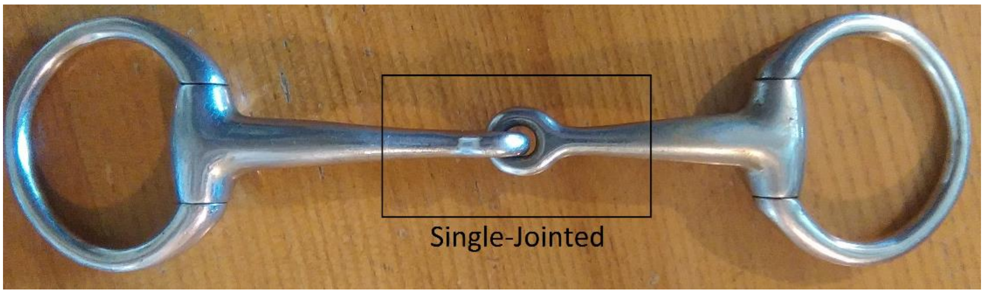

Figure 5. A Single-Jointed Snaffle (picture taken by the author).

Double-Jointed: This bit type is known for having no nutcracker action, it enables the horse to relax by dispersing the pressure on the bars of the mouth and lips. The bit itself follows the line of the horse's tongue meaning that when the reins are used it actually wraps around the tongue instead of pointing into the roof of the mouth (Vernon, 1998, pp. 39).

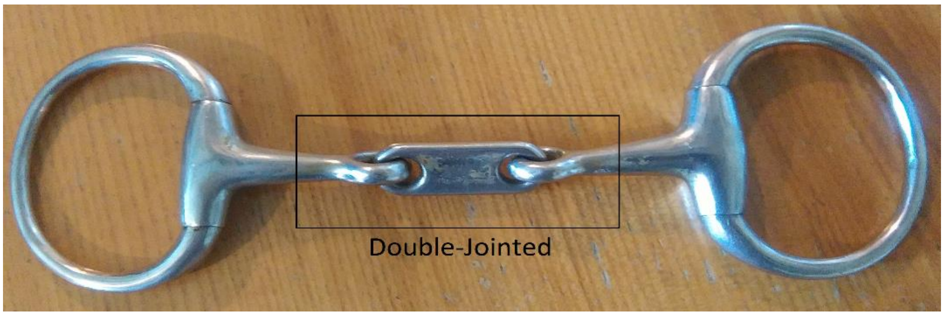

Figure21. A Double-Jointed Snaffle (picture taken by the author).

Table 22. The Bit Types used in the Bit Type Study.

Horse	Bit Type
1	Loose-Ring Single Jointed
2	Loose-Ring Double Jointed
3	Loose-Ring Full Cheek Single Jointed
4	Loose-Ring Full Cheek Single Jointed
5	Loose-Ring Full Cheek Single Jointed
6	Loose-Ring Full Cheek Single Jointed
7	Loose-Ring Full Cheek Single Jointed
8	Eggbutt Double Jointed (Lozenge)
9	Loose-Ring Happy Mouth
10	Eggbutt Double Jointed (Ball Joint)
11	Loose-Ring Full Cheek Single Jointed
12	Eggbutt Double Jointed (Lozenge)
13	Eggbutt Single Jointed
14	Loose-Ring Double Jointed (Bomber)
15	Loose-Ring Double Jointed (Bomber)
16	Loose-Ring Double Jointed (Bomber)
17	Eggbutt Single Jointed
18	Loose-Ring Double Jointed (Bomber)
19	Eggbutt Double Jointed (Myler)
20	Loose-Ring Double Jointed (Lozenge)
21	Hanging Cheek Double Jointed (Myler)
22	Loose-Ring Double Jointed (Lozenge)
23	Hanging Cheek Double Jointed (French-Link)
24	Loose-Ring Double Jointed (French-Link)
25	Loose-Ring Single Jointed
26	Loose-Ring Double Jointed (French-Link)
27	Eggbutt Single Jointed
28	Eggbutt Happy Mouth
29	Eggbutt Single Jointed

4.1.5. Rein Tension Gauge

The Centaur Rein Tension Device Professional edition S2013 (Centaur Trainology BV, PO Box 1034, 5200 BC ‘s-Hertogenbosch, The Netherlands) are calibrated to measure tension in Newton’s (N) with a capacity of 0 to 200N. The gauges have a 125% overload capability that equates with 250N, if tension above this is applied it may compromise accuracy. The gauges were calibrated (technology is self-calibrating) before each data collection and were inserted between the reins and bit of the bridle on both sides of the horse with each sensor weighing approximately 35g (Steenbergen, 2014, pp. 9). The sensors are connected via a short cable to the data logger which were attached using Velcro straps to either the back of the noseband or the throat lash depending on whether a noseband was present.

During the ridden stage the rider maintained a normal ‘contact’ and performed exercises in the three lower gaits, walk, trot and canter (Cross *et al*., 2017). The data collected by the gauges represents the tension transmitted along the reins between the bit and the rider’s hand and has a sensitive accuracy of up to 10g. The gauges record the data and it is transmitted via Bluetooth to a receiver connected to a USB port on a laptop. The gauges are able to transmit the data from a distance of up to 40m from the laptop with a transfer rate of 100 samples per second (100Hz). During the sessions the data is transferred to the accompanying Centaur computer software (Centaur.GUI) and is shown in real-time on the laptop through a series of readings that differ in frequency and magnitude (Clayton *et al*., 2003).

The graph consists of a vertical axis that represents the tension in Newton’s (N) while the horizontal axis corresponds to the time in seconds (s). 10 Newton’s is the equivalent of 1 kilogram of pressure (1kgF) applied to the reins whether it originates from the horse or rider. It is essential that the two gauges are attached to the correct rein as tension is shown through two lines on the graph; the red line represents the right rein while the green line corresponds with the left rein. Each step taken by the horse and rider correlates with the peaks shown on the graph.

4.1.6. Testing Protocol

The following unifying hypotheses were tested:

The null hypothesis (H_o): there is no significant impact on rein tension by bit type.

The alternative hypothesis (H_a): there is a significant impact on rein tension by bit type.

Throughout the data collection sessions the following steps where undertaken and repeated for each individual horse and rider dyad trialled:

1. The horse and rider entered the arena and commenced a normal warm-up of 5 to 10 minutes in length.
2. The rein tension gauges were calibrated and safely attached between the rein and bit of the bridle.
3. The test was completed by the horse and rider which involved carrying out a specific route around the arena in the first three gaits and on both rein directions using their normal bit type (see Appendix 10).
4. Once completed the rein tension gauges were safely removed before the horse and rider exited the arena.

The specific route around the arena completed by the horse and rider dyad during each test was determined according to the random crossover design (see Appendix 6). The routes differed in which rein direction the trial began on and which order the gaits where completed in (see Appendix 10).

4.1.7. Data Analysis

Although the recorded rein tension data were displayed graphically in the Centaur accompanying computer software (Centaur.GUI) it was not a sufficiently reliable or accurate method for analysing the vast volume of data. The data were therefore exported into Microsoft Excel 2013. However as the data would be analysed in Minitab v17 statistical software it was simpler to organise within that programme. The data were sorted into sets to identity particular variables resulting from both the horse and rider. The dependent variable was the rein tension while the independent variables were categorised into Rein Hand, Gait, Rein Direction, Bit Type (Ring), Bit Type (Joint), Horse Breed, Horse Age (Years), Horse Sex, Horse Height (hh), Rider Age (Years), Rider Sex and Ridden For (Years).

For statistical analysis a factorial AnOVa (analysis of variance) test was used (Petrie & Watson, 2006, pp. 97-106) with the level of significance set at $p<0.001$. The minimal, maximal and mean rein tensions were extracted to give an overall rounded evaluation of the rein tension: while a Post-hoc Tukey's test was performed to determine which levels of each variable were significantly different.

4.2 Results

There was a significant effect of bit type on rein tension (One-way Analysis of Variance: $F_{13,506}$=18.35; P<0.001; Table 23). Rein tension was highest for Hanging Cheek Double Jointed (Myler) and lowest for Eggbutt Double Jointed (Ball Joint). The six groups (shown as A, B, C, D, E and F in Table 23) differed significantly (Tukey's test details in caption of Table 23 and Appendix 11).

Table 23. The effect of Bit Type on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between bit types; same letters indicate no significant difference between bit types; multiple letters indicate significant differences with the other single letters, full details in Appendix 11.

Bit Type	Mean ± SE	Minimum (N)	Maximum (N)	Tukey's Grouping
Eggbutt (Full Cheek) Happy Mouth	9.594±0.539	6.875	13.595	A
Eggbutt Double Jointed (Ball Joint)	5.483±0.356	1.931	10.555	A B
Eggbutt Double Jointed (Lozenge)	13.247±0.511	6.403	22.685	A B C
Eggbutt Double Jointed (Myler)	9.091±0.627	5.410	12.389	B C D
Eggbutt Single Jointed	10.99±1.28	1.41	36.62	A B C D E F
Hanging Cheek Double Jointed (French-Link)	12.06±2.57	3.92	25.25	C D E
Hanging Cheek Double Jointed (Myler)	18.12±3.3	5.51	43.93	C D E
Loose Ring (Full Cheek) Single Jointed	7.473±0.316	1.192	24.060	C D E F
Loose Ring Double Jointed	15.881±0.771	7.129	24.233	C D E F
Loose Ring Double Jointed (Bomber)	10.67±1.08	1.28	35.10	D E F
Loose Ring Double Jointed (French-Link)	8.782±0.83	2.050	17.900	D E F
Loose Ring Double Jointed (Lozenge)	9.08±0.854	2.841	20.113	E F
Loose Ring Happy Mouth	8.399±0.345	4.779	13.573	F
Loose Ring Single Jointed	12.262±0.764	6.089	25.459	F

Rein tension was significantly impacted upon by Bit Type Ring (One-way Analysis of Variance: $F_{4,562}$=21.09; P<0.001; Figure 22). Rein tension was highest for Hanging Cheek (15.7±2.29N; Minimum: 3.92N; Maximum: 43.93N) followed by Loose Ring (11.154±0.388N; Minimum: 1.276N; Maximum: 35.104N), Eggbutt (10.633±0.479N; Minimum: 1.408N; Maximum: 36.616N), Eggbutt (Full Cheek) (9.594±0.539N; Minimum: 6.875N; Maximum: 13.595N) and lowest for Loose Ring (Full Cheek) (7.473±0.316N; Minimum: 1.192N; Maximum: 24.06N). These three groups (shown as A, B and C in Figure 22) differed significantly (Tukey's test details in caption of Figure 22 and Appendix 12).

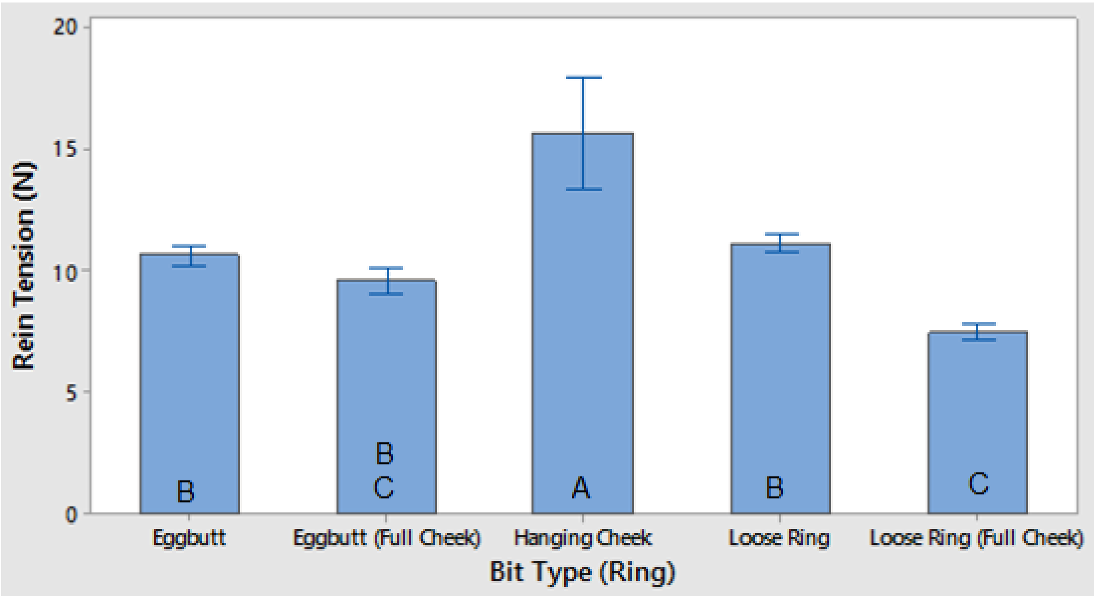

Figure 22. The effect of Bit Type (Ring) on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between bit types (ring); same letters indicate no significant difference between bit types (ring); double letters indicate significant differences with the other single letters), full details in Appendix 12.

There was a significant effect on rein tension by Bit Type Joint (One-way Analysis of Variance: $F_{7,526}$=16.42; P<0.001; Figure 23). Rein tension was lowest for Double Jointed (Ball Joint) (5.483±0.356N; Minimum: 1.931N; Maximum: 10.555N) followed in increasing tension by Happy Mouth (8.698±0.299N; Minimum: 4.779N; Maximum: 13.595N), Single Jointed (8.73±0.33N; Minimum: 1.192N: Maximum: 36.616N), Double Jointed (French-Link) (9.656±0.93N; Minimum: 2.05N; Maximum: 25.429N), Double Jointed (Bomber) (10.67±1.08N; Minimum: 1.28N; Maximum: 35.1N), Double Jointed (Lozenge) (12.206±0.474N; Minimum: 2.841N; Maximum: 22.685N), Double Jointed (Myler) (13.61±1.89N; Minimum: 4.779N; Maximum: 43.93N) and highest for Double Jointed (15.881±0.771N; Minimum: 7.129N; Maximum: 24.233N). The four groups (shown as A, B, C and D in Figure 23) are significantly different (Tukey's test details in caption of Figure 23 and Appendix 13).

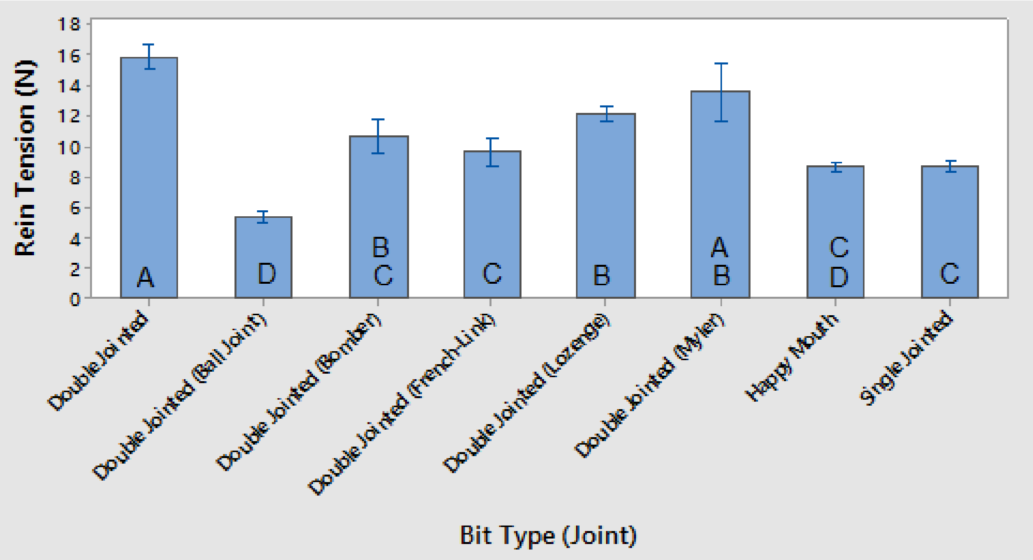

Figure 23. The effect of Bit Type (Joint) on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between bit type joint); same letters indicate no significant difference between bit type (joint) double letters indicate significant differences with the other single letters, full details in Appendix 13.

Gait had a significant effect on rein tension (One-way Analysis of Variance: $F_{2,506}$=16.19; P<0.001; Figure 24) with the tension increasing through the gaits from walk (8.102±0.285N; Minimum:1.383N; Maximum: 25.249N), to trot (9.676±0.4N; Minimum: 1.192N; Maximum: 36.616N), to canter (11.898±0.489N; Minimum: 1.276N; Maximum: 43.926N). The three gaits (shown as A, B and C in Figure 24) differed significantly from each other (Tukey's test in details in caption of Figure 24 and Appendix 14).

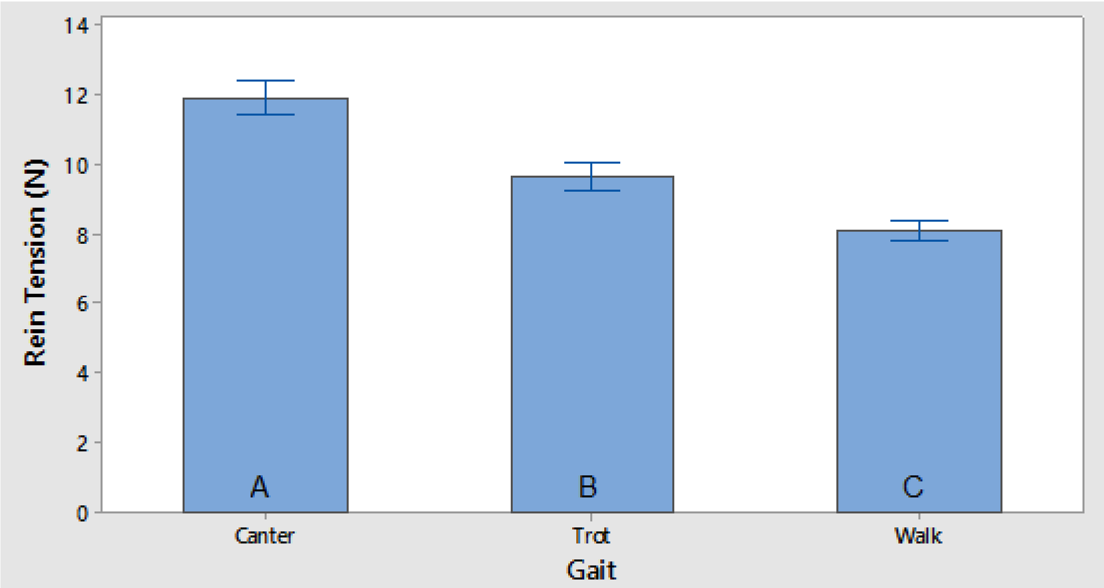

Figure 24. The effect of Gait on Rein Tension (N). Values are mean ± SE, see Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between the gaits (Tukey's T absolute values: 2.82 - 6.72; P<0.05); refer to Appendix 14 for Tukey details.

Rein tension was not significantly affected by either the rein hand (One-way Analysis of Variance: $F_{1,506}$=2.43; P>0.001; Left Rein Hand: 10.031±0.349N; Minimum: 1.192N; Maximum: 43.926N; Right Rein Hand: 9.702±0.323N; Minimum: 1.586N; Maximum: 37.48N) or the rider's rein direction (One-way Analysis of Variance: $F_{1,506}$=7.39; P>0.001; Left Rein Direction: 9.46±0.316N; Minimum: 1.192N; Maximum: 43.926N; Right Rein Direction: 10.275±0.354N; Minimum: 1.276; Maximum: 35.104N). The Post-hoc Tukey's test confirmed there was no significant difference between either rein hand (Tukey's T absolute value: 0.72; P>0.05; details in Appendix 15) or rein direction (Tukey's T absolute value: 1.89; P>0.05; details in Appendix 16).

Bit Type and Gait had a significant effect on rein tension (Two-way Analysis of Variance: $F_{26,506}$=3.86; P<0.001; Table 24)

Table 24. The effect of Bit Type and Gait on Rein Tension (N).

Rein Type	Gait	Mean ± SE(N)	Minimum (N)	Maximum (N)
Eggbutt (Full Cheek) Happy Mouth	Walk	8.225±0.456	6.875	8.804
	Trot	9.291±0.39	8.795	10.455
	Canter	11.27±1.12	8.27	13.59
Eggbutt Double Jointed (Ball Joint)	Walk	3.981±0.536	1.931	7.528
	Trot	5.088±0.44	3.296	8.694
	Canter	7.379±0.456	4.349	10.555
Eggbutt Double Jointed (Lozenge)	Walk	12.502±0.793	6.706	19.008
	Trot	12.776±0.932	6.403	18.938
	Canter	14.464±0.904	8.187	22.685
Eggbutt Double Jointed (Myler)	Walk	8.22±1.13	5.68	10.52
	Trot	8.18±1.06	5.41	10.12
	Canter	10.687±0.598	9.531	12.389
Eggbutt Single Jointed	Walk	10.15±1.27	3.5	18.54
	Trot	14.46±3.05	1.41	36.62
	Canter	7.48±1.03	2.18	13.76
Hanging Cheek Double Jointed (French Link)	Walk	17.85±2.63	13.61	25.25
	Trot	6.83±2.42	4.42	9.25
	Canter	5.7±1.78	3.92	7.37
Hanging Cheek Double Jointed (Myler)	Walk	9.1±1.74	5.51	12.47
	Trot	14.92±2.34	10.74	19.51
	Canter	30.34±5.57	16.64	43.93
Loose Ring (Full Cheek) Single Jointed	Walk	6.168±0.347	1.383	12.832
	Trot	6.858±0.47	1.192	17.472
	Canter	9.357±0.693	1.962	24.06
Loose Ring Double Jointed	Walk	11.724±0.936	7.129	15.816
	Trot	15.855±0.723	11.638	18.833
	Canter	20.06±1.06	13.08	24.23
Loose Ring Double Jointed (Bomber)	Walk	7.296±0.794	2.713	12.356
	Trot	11.6±1.47	3.9	21
	Canter	13.47±2.81	1.28	35.1
Loose Ring Double Jointed (French Link)	Walk	6.68±1.03	2.82	10.56
	Trot	10.435±0.61	8.097	13.061
	Canter	9.39±2.44	2.05	17.9
Loose Ring Double Jointed	Walk	6.95±1.46	2.84	14.6
	Trot	9.18±1.9	5.08	20.11

(Lozenge)	Canter	11.109±0.475	9.367	13.297
Loose Ring Happy Mouth	Walk	7.439±0.369	5.951	13.573
	Trot	7.868±0.51	4.779	10.216
	Canter	9.889±0.656	6.912	10.204
Loose Ring Single Jointed	Walk	8.132±0.428	10.81	12.025
	Trot	10.541±0.614	7.643	14.822
	Canter	18.11±1.14	10.81	25.46

Rein tension was significantly affected by Horse Age (One-way Analysis of Variance: $F_{12,609}$=23.03; P<0.001; Table 25), Horse Gender (One-way Analysis of Variance: $F_{1,620}$=40.14; P<0.001; Table 26), Horse Breed (One-way Analysis of Variance: $F_{17,604}$=22.72; P<0.001; Table 27) and Horse Height (One –way analysis of variance: $F_{12,609}$=7.66; P<0.001; Table 28).

Table. 25. The effect of Horse Age on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between horse age; same letters indicate no significant difference between horse age; multiple letters indicate significant differences with the other single letters,; refer to Appendix 17 for Tukey details.

Horse Age (Years)	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
6	9.352±0.602	4.857	16.555	A
7	8.520±0.848	3.502	20.113	A
8	15.059±0.908	2.820	43.926	A B C
9	10.154±0.388	5.410	23.569	B
10	12.171±0.51	1.276	35.104	A B C D E
11	5.483±0.356	1.931	10.555	A B C D
12	13.02±1.07	6.32	25.46	B C D
13	4.328±0.329	1.962	13.297	B C D E F
15	11.71±1.54	2.05	27.75	C D E F
17	6.613±0.408	1.192	22.239	D E F
18	12.06±2.57	3.92	25.25	E F G
22	8.399±0.345	4.779	13.573	F G
23	17.39±2.88	7.31	36.62	G

Table 26. The effect of Horse Gender on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between horse gender, refer to Appendix 18 for Tukey details.

Horse Gender	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
Gelding	11.179±0.3	1.931	35.104	A
Mare	8.242±0.358	1.192	43.926	B

Table 27. The effect of Horse Breed on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between horse breed; same letters indicate no significant difference between rein horse; multiple letters indicate significant differences with the other single letters,; refer to Appendix 19 for Tukey details.

Horse Breed	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
Andalusian	7.139± 0.901	2.841	13.297	A
Argentine Polo Pony	4.564±0.293	1.192	22.239	A B C
British Riding Pony	18.12±3.3	5.51	43.93	A C
Cob	7.381±0.696	1.408	13.595	A B C D
Cob X	9.091±0.627	5.410	12.389	A B C D
Hackney X Welsh Cob	8.399±0.345	4.779	13.573	B D E
Irish Draught	15.881±0.771	7.129	24.233	D E F
Irish Draught X Welsh D	5.483±0.356	1.931	10.555	B C D E F
Irish Sports Horse	9.53±1.32	2.82	17.90	F
Irish Sports Horse X Andalusian	9.537±0.665	4.460	17.971	E F
Lustiano	9.458±0.274	6.403	12.909	D E F G H
New Forest X Arab	15.43±1.56	8.85	25.46	E F
Sports Horse	11.02±1.25	5.88	20.11	D E F G H
Thoroughbred	15.54±2.42	7.02	27.75	F G
Unknown	11.78±1.59	1.28	35.10	F G H
Warmblood	9.803±0.528	3.502	23.569	F G H
Warmblood X	12.544±0.436	2.050	24.060	G H
Welsh X Arab	17.39±2.88	7.31	36.62	H

Legend: X = crossed with

Table 28. The effect of Horse Height (hh) on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between horse height; same letters indicate no significant difference between horse height; double letters indicate significant differences with the other single letters; refer to Appendix 20 for Tukey details.

Horse Height (hh)	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
14.0	4.725±0.789	1.408	8.331	A
14.1	9.11±1.25	2.84	25.25	A B
14.2	9.85±1.14	1.19	43.93	A B C D
14.3	9.594±0.539	6.875	13.595	A B C
15.0	11.969±0.856	6.403	35.104	A B C D E
15.1	8.271±0.469	2.820	22.239	B C D
15.2	6.282±0.362	1.276	20.113	A B C D E
16.0	7.88±0.907	2.050	10.612	A B C D E
16.1	10.77±0.379	1.931	24.060	C D E
16.2	12.981±0.735	3.502	27.749	A B C D E
16.3	10.216±0.812	6.317	15.638	E
17.0	11.205±0.814	6.089	23.569	D E

Rein tension was significantly affected by Rider Age (One-way Analysis of Variance: $F_{7,614}$=30.27; P<0.001; Table 29), Rider Gender (One-way Analysis of Variance: $F_{1,620}$=24.19; P<0.001; Table 30) and Length of time of the Rider has Ridden For (One-way Analysis of Variance: $F_{9,620}$=27.67; P<0.001; Table 31).

Table 29. The effect of Rider Age on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between rider age; same letters indicate no significant difference between rider age; double letters indicate significant differences with the other single letters; refer to Appendix 21 for Tukey details.

Rider Age (Years)	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
22	11.232±0.658	2.05	36.616	A
23	8.995±0.687	1.276	35.104	A
24	12.398±0.474	4.46	24.233	A
26	12.227±0.892	2.82	43.926	A B
48	5.563±0.386	1.192	13.573	B
49	5.483±0.356	1.931	10.555	C
53	5.483±0.391	1.962	22.239	C
63	12.782±0.480	4.062	23.569	C

Table 30. The effect of Rider Gender on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between the rider gender; refer to Appendix 22 for Tukey details.

Rider Gender	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
Female	9.346±0.264	1.192	43.926	A
Male	12.398±0.474	4.46	24.233	B

Table 31. The effect of Ridden For (Years) on Rein Tension (N). See Methods and Materials section 4.1 for sample size. Letters refer to Tukey's Post-hoc test, different letters indicate significant differences between ridden for; same letters indicate no significant difference between ridden for; double letters indicate significant differences with the other single letters,; refer to Appendix 23 for Tukey details.

Ridden For (Years)	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
3	2.726±0.157	1.192	4.847	A
4	5.483±0.356	1.931	10.555	A
8	12.398±0.474	4.460	24.233	A
12	8.995±0.687	1.276	35.104	A B
15	12.227±0.892	2.820	43.926	A B
20	11.232±0.658	2.050	36.616	B
38	8.399±0.345	4.779	13.573	B C
40	5.483±0.391	1.962	22.239	C D
53	13.571±0.576	4.062	22.685	C D
60	11.205±0.814	6.089	23.569	D

4.3 Discussion

Both Cook (1999) and Quick and Warren-Smith (2009) imply that the use of a foreign object such as the bit in the horse's mouth can result in pain and discomfort. However, a correctly fitted bit, used humanely, is a common method for controlling the direction and speed of movement in ridden and unridden horses. Currently, there is a considerable variety of bit types available, differing in design, size, intended usage and severity (Vernon, 1998, pp. 30-31; Batty-Smith, 2008, pp. 244; Doherty *et al*., 2017). In 1965 Tuke (pp.32) listed bit types in what was believed to be the order of severity (Table 26). For comparison, the limited number of bit types trialled in this study were categorised in order of rein tension from low to high using the mean ± standard error values.

Table 32. Comparison of Bit Type in Relation to Severity and Rein Tension.

Tukes' (1965) list of bit types in order of severity (from low to high):	**Snaffle Bit types trialled in this study in order of rein tension (from low to high):**
Fixed Ring, Straight Bar, Mullen Mouth	Eggbutt, Double Jointed, Ball Joint
Fixed Ring, Straight Bar, Metal Mouth	Loose Ring, Full Cheek, Single Jointed
Loose Ring, Straight Bar, Mullen Mouth	Loose Ring, Happy Mouth
Loose Ring, Straight Bar ,Metal Mouth	Loose Ring, Double Jointed, French-Link
Fixed Ring, Single-Jointed (Thick)	Loose Ring, Double Jointed Lozenge
Loose Ring, Single-Jointed (Thick)	Eggbutt, Double Jointed, Myler
Loose Ring, Full Cheek, Single-Jointed	Eggbutt, Full Cheek, Happy Mouth
Fixed Ring, Single-Jointed (Thin)	Loose Ring, Double Jointed, Bomber
Flat Ring, Jointed, (Thin)	Eggbutt, Single Jointed
Fixed ring, Full Cheek, Single-Jointed, (Thin)	Loose Ring, Single Jointed
Hanging Cheek, Single-Jointed	Hanging Cheek, Double Jointed, French Link
Loose Ring, Lozenge	Eggbutt, Double Jointed, Lozenge
Loose Ring, (Thin)	Loose Ring, Double Jointed, Not Specified
D-Ring Snaffles	Hanging Cheek, Double Jointed, Myler

Legend: Thin = narrow mouthpiece, Thick = Wide mouthpiece.

Comparison of these categorisations highlighted the bit types recorded within the second column are mostly in the opposite order than compared to the first; this finding although confusing at first would align with the theory that the higher the bit severity the less degree of applied pressure is required to elicit a desired response from the horse. For example, a common misconception is that the thinner the bit the lighter and kinder it will be (Batty-Smith, 2008, pp. 246; Vanderhost *et al*., 2013); it is thick bits that are actually safer for maintaining the welfare of the horse (Tuke, 1964, pp. 25; Vernon, 1998, pp. 37). However, following the suggested theory, less pressure would need to be applied to the thinner bit than compared to thicker one to receive the same desired response from the horse (Manfredi *et al*., 2009; Eiseriö *et al*., 2013). In turn, if less pressure is applied to receive the response it has the potential to prevent scenarios where the pressure is constantly being increased until the horse becomes habituated or learned helplessness occurs (Warren-Smith *et al*., 2007; McGreevy and McLean, 2010). Nevertheless it should be understood that this theory is not advocating the use of severe bits in situations that are not warranted as it will potentially compromise the welfare of the horse. Furthermore these findings have highlighted the requirement for further substantial research into the exact effect of bit type on the horse along with potential impacts on training, performance and welfare.

Within Equitation Science, bit type research in relation to rein tension is an ever-growing important area of investigation (Pierard *et al*., 2015). Currently the precise distribution of pressure across the horse's mouth from the bit is still undetermined (Eiseriö *et al.,* 2015). Previous research has shown that the degree of pressure that the horse experiences is effected by a number of variables including the size and shape of the bit, how the bit is fitted, the position of the horse's head and neck and oral cavity anatomy (Eiseriö *et al.,* 2015; Doherty *et al*., 2017; Dyson, 2017). The Post-hoc Tukey's test results of Bit Type (Joint) analysis divided the eight trialled bit types (joint) into four groups (refer to Figure 32 and Appendix 13). Of these eight bit types (joint) five were shown to be significantly different (represented by one letter; Double Jointed French Link and Single Jointed were not significantly different). The three remaining bit types (Double Jointed Bomber, Double Jointed Myler and Happy Mouth) were represented by two letters highlighting significant differences with the other single letters). In comparison the Post-hoc Tukey's test results for Bit Type (Ring) were more defined. The five types trialled were represented by three groups (A, B and C; refer to Figure 22 and Appendix 12) with only one type (Eggbutt Full Cheek) characterised by two letters. Although these results are preliminary and require further work with an increased sample it highlights the requirement for an adequate level of understanding of bit action as inappropriate usage by the rider may occur causing the horse to experience confusing signals, discomfort and the potential for compromising welfare (Benoist & Cross, 2016b).

Cross *et al.* (2017) state the exact motion of the bit could be determined within a laboratory environment. However the live experimental situation, consisting of the rider's hand, the horse's mouth and the bit provides the optimum location for data collection and analysis. Although rein tension is a valuable assessment tool to analyse the pressure between the rider's hand and the horse's mouth it does not provide an explanation regarding the precise action of the bit across the horse's oral cavity for two reasons (Cross *et al*., 2017). The first is to presume the bit transfers pressure from the reins to the horse's mouth in only place; therefore the tension could be measured in Newtons (N) using rein tension devices. However the second is to understand that the bit actually distributes applied pressure to a number of areas within the horse's mouth making it difficult to accurately evaluate the levels of tension. Therefore highlighting the first option as the most accurate method for analysing the effect of bit type on rein tension and was the reasoning for the use of rein tension devices during this research. However future work involving bits would benefit from pressure sensors being placed onto the bit in specific locations where tension may be transmitted (Doherty *et al.,* 2017a).

When evaluating rein tension data it is difficult to determine the impact on the horse as the exact distribution of applied pressure across the horse's mouth by the bit is currently undetermined (Eiseriö *et al*., 2015). Further research into this area of investigation would benefit from the use of an ethogram (Hall & Heleski, 2017); each behaviour exhibited by the horse is recorded and compared to the ethogram to evaluate the psychological and physical effect on the ridden horse. Future work that implements rein tension, ethograms and the influence of horse and rider biomechanics as methods of analysis have the potential to determine at which point the pressure applied becomes painful and aversive for the horse (Hall & Heleski, 2017); while providing greater understanding of training techniques in relation to horse performance and welfare.

The minimal, maximal and mean rein tensions are all measures of magnitude (Clayton *et al.,* 2003), and as revealed by the results increase in conjunction with the gaits. Walk maintained the least degree of pressure while canter maintained the highest (Walk<Trot<Canter). However as the results highlighted the mean tensions reported are significantly lower than the maximum tensions. In future research it is advised as Eiseriö *et al.* (2015) suggest that maximum tensions are not analysed due to being rare occurrences; which may potentially have resulted due to the horse coughing, tripping, shying, or from pulling the reins. Theses anomalies have the potential to produce an inaccurate picture of the rein tension the horse has been subjected to. However due to the method in which the data was analysed the maximum tensions reported are an average of the overall tension rather than the specific highest tension recorded; therefore producing a more applicable analysis. Future work may also benefit from investigating the rise time, loading rate and impulse rate in order continue to produce a rounder analysis of the collected data (Clayton *et al.,* 2011) and the potential impact on the horse.

Although the thesis followed and implemented the experimental design there are a few areas for improvement regarding future research. First, a portion of the data were collected within the teaching of an undergraduate programme at a college and therefore safety and learning of the students was paramount. However this creates the potential for compromising accuracy and reliability. Second, the data although collected in arenas with the same surface type occurred across multiple locations, varying in indoor and outdoor arenas. Although scientific research principles strive for uniformity in data collection to increase accuracy, reliability, validity and precision (Randle *et al*., 2017) an aim of the study was to collect the data within an environment that accurately reflects everyday equestrianism practice so the outcomes are of greater applicability to the general horse practitioner. Third, as the horse is a live animal it is difficult to acquire large sample sizes. Although the study trialled twenty-nine horses only a small number of bit types were investigated (five bit ring types and eight bit joint types). Fourth, when conducting research using horses specifically looking at rein tension it is difficult to control each potentially contributing variable. The consequences of data being collected over a period of time across multiple locations are the small sample size and each specific route the horse and rider dyads undertook may not have been precise. Nevertheless it should be noted each horse and rider dyad only partook in one test each, therefore eliminating the possibility of an impact from order effect or fatigue. Although the riders used for the study were of similar riding ability, for standardisation it would be preferable during future work that the horses and riders are more uniform in training ability, no riders carry whips, all horses wear the same noseband type of or none and the data is collected in one location (Egenvall *et al*., 2012). Implementation of these points have the potential to result in the research being of greater relevance and applicability to the equestrian industry while improving and informing the general equitation practitioner and practice (Randle & Waran, 2017).

4.4 Conclusion

Through Equitation Science and the use of technology it has been demonstrated that objective evidence-based quantitative data may be collected in order to determine the effect of specific variables on rein tension in relation to the ridden horse. The study has highlighted that bit type including the type of ring and joint have a significant effect on rein tension. The Eggbutt Double Jointed (Ball Joint) was shown to maintain the least tension while the Hanging Cheek Double Jointed (Myler) maintained the highest. Analysis of Bit Type (Ring) revealed tension to be highest for Hanging Cheek and lowest for Loose Ring (Full Cheek). While for Bit Type (Joint) the Double Jointed (Ball Joint) maintained the lowest tension and Double Jointed (Not Specified) maintained the highest. The results suggest that the severity of bit type influences the level of tension applied, i.e. the greater severity of bit type the lesser degree of tension required to receive a desired response. However this research is preliminary due to the limited number of times each bit type was trialled as a result of conducting the study within an environment that accurately reflects the equestrian industry. Although it should be noted that preliminary investigations set an important starting point for further work as it produces a range of baseline data that future research can be founded upon. Therefore there is an essential requirement for further research to be conducted within this area with a greater sample size to determine the effects of bit type in relation to training, performance and welfare of the ridden horse.

5. **Discussion**

Previous research (Clayton *et al.,* 2003; 2005; Heleski *et al.,* 2009; Eiseriö *et al.,* 2015) using rein tension devices to accumulate data has produced reliable results. It is essential that rein tension gauges are able to measure the entire range of tensions produced in the ridden horse and similar to Egenvall *et al.* (2012) and Christensen *et al.* (2014) a benefit of the rein tension device used for both rein tension studies was its broad measuring range (up to 250N); resulting in no peaks of rein tension being cut off while still recording small variations (Eiseriö *et al.,* 2015). However to accurately measure rein tension the device must be light to prevent interference with the ridden session (Clayton *et al.,* 2003) while being sufficiently robust to be used with horses. This was a problem experienced by Preuschoft *et al.* (1999) research which used sensors weighing 300g, preventing use on both reins simultaneously. Whereas the device used for this thesis weighed approximately 70g and was therefore believed to be light enough not to effect the data collected. Öhmans (2009) research discovered a difference of 0.1kg between the left and right sensors used and may have created errors within the data. Regardless of weight it is essential that the device is calibrated correctly due to susceptibility of over loading and environmental temperatures (Clayton *et al.,* 2011). For instance, humidity and temperature are conditions that will change as the horse and rider work. However it has yet to be determined at which point the rein tension gauges become affected; to control for this limitation it is essential correct calibration of the device occurs. The device used for these two rein tension studies was calibrated (self-calibrating technology) before each individual data collection session; therefore it can be assumed that accurate, reliable and valid results were produced.

The accuracy at which rein tension gauges measure tension is strongly debated as during conversion of the data from analogue to digital results in the loss of large amounts (Pierard *et al*., 2015). This is concerning and highlights that results produced by both studies should be taken as approximations and with caution. As technology advances this limitation would benefit from rectification resulting in research that is increased in accuracy, precision and validity. However until technology improves it is advised that limitations of the devices used within studies are documented and continuation of statistical comparison across similar research (i.e. meta-analysis) will enable further understanding of the limitations and how the riders applies and the horse receives a signal. Future rein tension devices would also benefit from two main advancements. Firstly, either wireless data loggers or gauges that are built into the actual reins (Warren-Smith *et al*., 2007; McGreevy *et al*., 2014; Pierard *et al*., 2015); which would minimise the weight of extra equipment on the horse and minimise the potential impact on the recorded rein tension. Second, automatic linking of the rein tension gauges to real-time surveillance (Pierard *et al*., 2015); this feature would provide a stronger method of analysis and evaluation as the raw data may be matched to observational data leading to increases in the accuracy of what the applied tension is representing. These changes would further underpin equitation science principles within research including improving and enhancing future research.

A lack of video analysis is not only a limitation in relation to the rein tension device itself; it is also a limitation regarding the potential effect of speed and direction of movement and the biomechanics of the horse and rider on the recorded rein tension data. For both studies the horse and rider pairs were asked to ride as normal in the arena; however in terms of analysis this cannot be quantified or the potential impact on rein tension understood. Clayton *et al*. (2011) describe how reflective markers can be attached to the horse’s wither and mid laterally to each forehoof to determine footfall sequence and speed of the horse and rider. Therefore when analysed in conjunction with rein tension, such data can determine whether the changes in tension occurred due to the speed and direction of movement. Each horse and rider pairing is unique as is the rein tension that is applied; calculating the speed of movement would show firstly whether it is the effector responsible for the change in rein tension and secondly produce a more rounded analysis and evaluation of the rein tension applied. The biomechanics of both the horse and rider are important factors when considering movement whether direction or speed. As Clayton and Hobbs (2017) explain the horse and riders movement should be as one fluent being; i.e. employing an independent seat where the rider is able to move parts of the body independently (Goodwin *et al*., 2008). Without correct balance the rider is unable to efficiently or successfully influence the speed and direction of the horse's movement (Clayton & Hobbs, 2017). With video analysis the movement of both horse and rider can be directly linked to the rein tension enabling detailed evaluation. Whether the rider is balanced, maintaining control and if the horse and rider are collected (Eiseriö *et al*., 2015); which can be difficult to determine without pictorial evidence. Therefore further highlighting the necessity for video analysis to be an integral part of rein tension research, enabling greater understanding of the impact of rider and horse biomechanics on movement and in turn on rein tension.

Eiseriö *et al*. (2013) report that due to the intricacy of the variations that effect rein tension it is difficult to determine whether the discrepancies have occurred due to the horse, the rider or factors including the environment (Heleski *et al*., 2009). For that reason the following variables were considered individually (Eiseriö *et al*., 2015): Left Rein Hand, Right Rein Hand, Left Rein Direction, Right Rein Direction, Gait, The Horse (Breed, Age, Sex and Height) and The Rider (Gender, Age and Length of Time Riding). These numerous variables further highlight the complexity (Eiseriö *et al*., 2013) of analysing and evaluating the interactions between the horse and rider through rein tension.

Similar to previous research (Clayton *et al*., 2011; Eiseriö *et al*., 2015) each peak of the recorded rein tension occurred during the middle of the horse's stride which corresponds with the horse receiving minimal to no pressure being maintained by the rider. The degree of each peak also correlated with the gait of the horse while the level of rein tension recorded increased as the horse moved up through the gaits (Walk<Trot<Canter) and was evident in both rein tension studies

According to Eiseriö *et al*. (2015) evenness across both sides of the body is a goal within training and makes evaluation of the inconsistencies between the riders left and right rein hands and the left and right rein direction of movement intriguing. It has been previously reported that approximately 87 to 90% (Cashmore, 2009) of riders exhibit a right hand preference when undertaking motor tasks (Hawson *et al*., 2014). However the results from the study investigating the effect of rein type on rein tension do not align with Cashmore's (2009) finding as there was no significant difference between the riders left or right rein hands. Furthermore the rein tension recorded in the left rein hand was slightly lower however minimally less consistent than the right rein hand tension. However in contrast the results of the third study the effect of bit type on rein tension do corresponded with those of Cashmore (2009). The rider's right hand maintained although not significant a slightly lower and more consistent level of tension than compared to the rider's left rein hand. According to Hawson *et al*. (2014) the rider's non-preferred hand will have the stabilising role whereas the preferred hand carries out the fine movement (de Poel *et al*., 2007). Earlier research by Bagesterio and Sainburg (2003) indicated that the rider's non-preferred hand is more reliant on information gained visually than compared to proprioceptive feedback. This is a surprising conclusion as proprioceptive feedback is more relevant as it provides information in relation to the balance and movement of the body (Goble & Brown, 2008). Analysis of the effect of rein hand and rein direction on rein tension revealed that in both rein tension studies the riders maintained a higher tension on the inside rein than compared to the outside in conjunction with the rein direction (Appendix 24). However the rein tension applied was more consistent in the rider's right rein hand regardless of rein direction; therefore implying the right rein hand may be the dominant hand. Nevertheless as both studies trialled in this research have differing results it cannot be concluded which hand is dominant as the rider's preference was not recorded. Therefore further highlighting the essential requirement of future research to record rider laterality and preference in order to develop understanding regarding the effect of the rider on the horse.

In comparison to many authors (McGreevy & Rogers, 2005; Austin & Rogers, 2007; Kuhnke *et al*., 2010) believing that the discrepancies in rein tension are due to horse laterality, Warren-Smith *et al.* (2007) suggest that it is a result of the rider i.e. biomechanics. According to Warren-Smith *et al.* (2007) through the analysis of minimum, maximum and mean rein tensions on a variety of collected data the rein tension maintained by riders has not been found to be consistent in any single rider;

with significant differences between the minimum and maximum tensions reported. Therefore potentially causing an influence on the efficiency and effectivity of signals applied in a similar manner to those resulting as an impact of rider laterality. Furthermore Garner and Shim (2008) suggest that combined with laterality, the rider's ability in upper body pulling strength may potentially be causing the negative impact. For instance, high levels of tension may be as difficult to consistently maintain as low level rein tension (Hawson *et al.,* 2014). Therefore given the significance of consistency it would be beneficial that future research implement the use of minimal riders which have similar riding skill, ability and discipline to reduce the potential impact when analysing rein tension in relation to horse performance and welfare.

Due to the rein tension devices being calibrated correctly during data collection Warren-Smith *et al*. (2007) report the discrepancies observed in the data may be a result of a lack of understanding on whether it was pressure signals or tension being evaluated. The misinterpretation emphasises the requirement for further understanding on maintaining a low but consistent rein tension throughout ridden work. The results of both the quantitative studies indicated that desired responses from the horse can be exhibited through the application of low level pressure. Therefore it is essential that the use of rein tension devices in both research and day to day training is continued so that low but consistent levels of tension are further maintained, developed and promoted. If implemented effectively it will employ proven research supported methods of training within practice, increase the reliability of data collected within equitation research and potentially improve the welfare of the ridden horse (Randle *et al*., 2017).

Although a range of pressures are required to elicit specific responses from each individual horse it is widely understood that a light connection should be consistently maintained (Warren-Smith *et al*., 2007). However as often the case, the rider's perception of the pressure being applied is inherently different to the tension that is in fact applied (Clayton *et al*., 2003; Randle et al., 2011). Similarly, riding with a rein tension device will also have a psychological effect on the rider (Eiseriö *et al*., 2015); resulting in the rider potentially adjusting their own riding technique to not only increase the horse's performance but also their own during data collection sessions. In relation to the horse and rider it is essential that rider's increase awareness of the rein tensions that are applied while minimising the levels and maximising the consistency (Warren-Smith *et al*., 2007); which is possible with the use of rein tension devices. Furthermore the impact of rider perception essentially needs to be minimised. For these current studies the riders that participated were requested to ride as per normal during data collection; therefore limiting the effect of rider perception on the resulting data.

Each individual horse requires different levels of rein tension to be applied to elicit a desired response (Warren-Smith *et al.,* 2007). This statement has been further confirmed as the physical characteristics (breed, sex, age and height) of the participating horses was shown to have a significant effect on rein tension. These differences may have been further exacerbated by the horses backgrounds and training histories. Similarly the rider (age, sex and length of time ridden for) was revealed to have a significant impact on rein tension. However, to confirm the finding is not an anomaly further research is required using an increased sample size. Furthermore multiple authors including Murray *et al*. (2006) and König von Borstel *et al*. (2011) highlight that when comparing individual riders together there will be differences in variables including the ability to adapt to specific movements (Scollhorn *et al*., 2006). The samples would therefore be required to be sub-divided into categories with horses of a similar age, breed, sex, and height and riders of sex, age and riding ability; to enable accurate evaluation of the potential effects on rein tension to determine the full extent of the effect on both performance and welfare of the ridden horse. Therefore it is a worthy area of investigation and important finding as previous research (Murphy *et al.,* 2005; Warren-Smith *et al*., 2007) has reported similar results.

Obtaining large sample sizes within equitation research can be problematic as it is often determined by practical considerations (Pierard *et al*., 2015) that are usually increased when both horse and human participants are involved. Ascertaining a large sample size of voluntary participants in one environment within the industry that are fed, housed and ridden homogenously is unlikely due to the limiting factors involved including expenses, time, willingness and the uncontrolled variation of owners. Pierard *et al*. (2015) explain small sample sizes are adequately acceptable if the characteristics of both horse and rider participants are recorded as consistent methodology and reporting in relation to small sample sizes allows results to be compared across multiple studies enabling enhanced research. However both methodological issues and smaller sample sizes continue to negatively affect research; which is a problem seen throughout this research. Previously published studies have used a range of sample sizes that contained four, eight, twelve, fifteen, twenty-two and twenty-nine (Heleski *et al*., 2009; Clayton *et al*., 2011; Manfredi *et al*., 2005; Christensen *et al*., 2014; Warren-Smith *et al*., 2007; Kienapfel *et al*., 2014) subjects respectively. The two rein tension studies recruited sample sizes of fifteen and twenty-nine horse and rider parings respectively and are within the range reported in previous research. Furthermore characterisations of each horse and rider were recorded and although a number of horses were from different environments there was no sign of dependency or clustering (Eiseriö *et al*., 2015); therefore it could be concluded that the number of subjects used were acceptable in producing reliable and accurate results. However for the study examining rein type, of the fifteen horse and rider pairings each set trialled only two of the five rein types; i.e. each rein type was tested six times. This sample size is on the lower end of the spectrum stated by the previous research, classifying it as a preliminary investigation and therefore may have influenced the results (Quick & Warren-Smith, 2009). The bit type study recruited a sample size of twenty-nine horse and rider pairings, the number of times each bit type was trialled (Table 27) was random and inconsistent in comparison to the rein type study. The reliability of these results can be argued in two ways. First, an aim of the study was to follow and further develop the theme of the survey in determining the bit types within the snaffle family used by the equestrian population and report baseline rein tension data for these types. Therefore a preliminary investigation that future research can commence from. However and more importantly although statistical analysis to an extent can cope with the differing number of times each bit type was trialled it does not enable particularly reliable or accurate comparison of rein tension between the types. Therefore further highlighting the issue of sample sizes within this research; which was predominantly a result of rider, horse and equipment availability, expenses and time. Pierard *et al*. (2015) explain that an optimum sample size occurs as a result of equating statistical power against the practicality of acquiring an adequately sized sample. Furthermore implementing a priori sample size calculation into the experimental design of future research will support in determining the optimum sample size; in turn producing increased accurate and reliable results and is a method neglected in this research. Therefore the sample sizes used in these rein tension studies are limited causing potential that the data may not be appropriately extrapolated to other horses or reliably proven to be a precise portion or representation of the equestrian population (Eiseriö *et al*., 2013; 2015).

Table 3. Allocation of each Bit Type trialled in The Bit Type Study.

Bit Type	**Number of times each bit type was trialled.**
Loose-Ring Single Jointed	2
Loose-Ring Double Jointed (Not Specified)	1
Loose-Ring Full Cheek Single Jointed	6
Eggbutt Double Jointed (Lozenge)	2
Loose-Ring Happy Mouth	1
Eggbutt Double Jointed (Ball Joint)	1
Eggbutt Single Jointed	4
Loose-Ring Double Jointed (Bomber)	4
Eggbutt Double Jointed (Myler)	1
Loose-Ring Double Jointed (Lozenge)	2
Hanging Cheek Double Jointed (Myler)	1
Hanging Cheek Double Jointed (French-Link)	1
Loose-Ring Double Jointed (French-Link)	2
Eggbutt Happy Mouth	1

It is important to acknowledge and understand that when undertaking equitation research numerous complex complications arise which are not easily rectified. Therefore when conducting research there is a necessity for maintaining scientific principles and integrity while preventing compromising of horse welfare (McIlwraith, 2011). This is achieved though experimental design by adhering to ethical principles and considering replacement, reduction and refinement (Russell & Burch, 1959; Rollin, 2006b; Randle *et al*., 2017). In regard to the quantitative studies it was unviable to replace the horse with non-live apparatus as the study aimed to determine the effect of rein and bit type on rein tension in the ridden horse. If the horses were replaced with a static model the data produced would not be easily relatable or applicable to the horse, rendering it irrelevant in this specific situation. Correct implementation of refinement of both investigations enabled the rules and regulations of horse care to be maximised, including the horse neither being removed from nor the disruption of the normal environment (Rollin, 2006a). Furthermore the number of horses used within both studies were of a similar level preventing compromising of experimental design and statistical analysis (McIlwraith, 2011). Nevertheless it is important to ensure that research is free from bias so that valid conclusions are attained. The author had no personal or financial relationship with other organisations or people that could inappropriately bias or influence the contents of the thesis, therefore evaluation of the data occurred successfully without compromising accuracy, validity, reliability, precision or the welfare of the horses used (Randle *et al*., 2017).

6. Conclusion

The thesis comprised of three separate and yet interlinked studies. The first comprised of a qualitative survey which revealed Rubber reins and the Snaffle family to be the most commonly used type of reins and bit types by the equestrian industry. The second investigated the effect of rein type on rein tension; highlighting Rubber reins also the most commonly used to maintain the highest level of tension while Thin leather reins maintained the least tension. The third study aimed to produce data for a range of bit types originating from the Snaffle family. Of the fourteen bit types trialled the recorded rein tension was lowest for the Eggbutt Double Jointed (Ball Joint) bit type and highest for the Hanging Cheek Double Jointed (Myler).

Rein tension is a continually expanding and developing area of Equitation Science that highlights the importance of promoting further understanding of equitation concepts through academia and the equestrian industry. Current research is focusing on training of the horse with rigorous use of the principles of learning theory in relation to welfare (Eiseriö *et al*., 2015). Further research that provides objective evidence-based data will enable continued evaluation of the minimal, maximal and mean rein tensions (Clayton *et al*., 2011) that are required to receive a desired response. Rein tension measurement will also enable further analysis of the variables that effect the level of tension and the impact it has on the physical, physiological and psychological wellbeing of the horse. In turn this will potentially lead to the enhancement and improvement of communication between the horse and rider, training techniques, and the design and development of tack and equipment. Furthermore future research into rein tension is essential for ethical and sustainable equitation (Randle *et al*., 2013) and the welfare of the ridden horse.

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8. Appendices

8.1. Appendix 1: The Survey.

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<u>Reins</u>

IN PARTNERSHIP WITH PLYMOUTH UNIVERSITY

How old are you?

Sex: Male ☐ Female ☐

How long have you been riding for?

1. What discipline do you compete in?

2. Do you take part in affiliated or unaffiliated competitions?

3. What level do you compete at?

4. What type of bridle do you normally use and why?

5. What type of bit do you normally us for exercise, for training, for competition and why?

6. What type of reins do you normally use for exercise, for training, for competition and why?

8.2. Appendix 2: Details of the horses tack used in the Rein Type Study.

Horse	Bridle Type	Noseband	Flash Noseband	Bit Type
1	Standard Leather	None	None	Loose Ring, Single Jointed Snaffle (Stainless Steel)
2	Standard Leather	Cavesson	None	Loose Ring, Double Jointed Snaffle (Stainless steel)
3	Standard Leather	None	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
4	Standard Leather	None	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
5	Standard Leather	None	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
6	Standard Leather	None	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
7	Standard Leather	Crank	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
8	Standard Leather	Cavesson	None	Fixed Ring, Lozenge Snaffle (Stainless Steel)
9	Standard Leather	Cavesson	None	Fixed Ring, Lozenge Snaffle (Stainless Steel)
10	Standard Leather	Cavesson	None	Loose Ring, Happy Mouth Snaffle
11	Standard Leather	None	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
12	Standard Leather	None	None	Full Cheek, Fixed Ring, Ball Jointed Snaffle (Stainless Steel)
13	Standard Leather	Crank	None	Full Cheek, Loose Ring, Single Jointed Snaffle (Stainless Steel)
14	Standard Leather	Cavesson	None	Fixed Ring, Lozenge Snaffle (Stainless Steel)
15	Standard Leather	Cavesson	None	Full Cheek, Fixed Ring, Single Jointed Snaffle (Stainless Steel)

8.3. Appendix 3: The rein types trialled by the horse and rider dyads used in Test One and Test Two of the Rein Type Study.

	Test One					Test Two				
HR	Rubber	Continental	Thin Leather	Thick Leather	Laced Leather	Rubber	Continental	Thin Leather	Thick Leather	Laced Leather
1	N								A	
2				A		N				
3				N		A				
4				N						A
5				N						A
6			N				A			
7				N		A				
8		N						A		
9	A									N
10			A			N				
11		N								A
12					A			N		
13			N				A			
14			A				N			
15		A								N

Legend: N = Normal Rein Type, A = Alternative Rein Type, HR = Horse and Rider Pairings,

= The rein type trialled by the Horse and rider dyad.

8.4. Appendix 4: The routes trialled by the horse and rider dyads used in Test One and Test Two of the Rein Type Study.

		Test	One			Test	Two	
HR	Route 1	Route 2	Route 3	Route 4	Route 1	Route 2	Route 3	Route 4
1	■					■		
2			■					■
3		■					■	
4	■							■
5		■			■			
6		■						■
7	■					■		
8				■			■	
9		■					■	
10	■					■		
11				■			■	
12	■					■		
13				■			■	
14	■							■
15	■					■		

Legend: HR = Horse and rider dyads, ■ = The trial that was carried out by the horse and rider pair.

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Route 1 to be carried out for The Rein Type Study

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1. From K walk a square K-E-B-F on the right rein.
2. At K repeat step one in trot.
3. At K transition into canter going large, maintain canter from K through E-H-C-M-B-F-A. On reaching A transition down into trot and then walk.
4. On returning to K repeat steps 1 to 3 two times. Once repeated move onto step 5.
5. Change the rein.
6. At F walk a square F-B-E-K on the left rein.
7. At F repeat step one in trot.
8. At F transition into canter going larger, maintain canter from F through B-M-C-H-E-K-A. On reaching A transition down into trot and then walk.
9. On returning to F repeat steps 6 to 8 two times. Once repeated move onto step 10.
10. At F halt to end the trial.

Route 2 to be carried out for The Rein Type Study

1. From F walk a square F-B-E-K on the left rein.
2. At F repeat step one in trot.
3. At F transition into canter going larger, maintain canter from F through B-M-C-H-E-K-A. On reaching A transition down into trot and then walk.
4. On returning to F repeat steps 1 to 3 two times. Once repeated move onto step 5.
5. Change the rein.
6. At K walk a square K-E-B-F on the right rein.
7. At K repeat step one in trot.
8. At K transition into canter going large, maintain canter from K through E-H-C-M-B-F-A. On reaching A transition down into trot and then walk.
9. On returning to K repeat steps 6 to 8 two times. Once repeated move onto step 10.
10. At K halt to end the trial.

Route 3 to be carried out for The Rein Type Study

1. From K trot a square K-E-B-F on the right rein.
2. At K repeat step one in walk.
3. At K transition into canter going large, maintain canter from K through E-H-C-M-B-F-A. On reaching A transition down into trot and then walk.
4. On returning to K repeat steps 1 to 3 two times. Once repeated move onto step 5.
5. Change the rein.
6. At F trot a square F-B-E-K on the left rein.
7. At F repeat step one in walk.
8. At F transition into canter going larger, maintain canter from F through B-M-C-H-E-K-A. On reaching A transition down into trot and then walk.
9. On returning to F repeat steps 6 to 8 two times. Once repeated move onto step 10.
10. At F halt to end the trial.

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Route 4 to be carried out for The Rein Type Study

IN PARTNERSHIP WITH PLYMOUTH UNIVERSITY

1. From F trot a square F-B-E-K on the left rein.
2. At F repeat step one in walk.
3. At F transition into canter going larger, maintain canter from H through B-M-C-H-E-K-A. On reaching A transition down into trot and then walk.
4. On returning to F repeat steps 1 to 3 two times. Once repeated move onto step 5.
5. Change the rein.
6. At K trot a square K-E-B-F on the right rein.
7. At K repeat step one in walk.
8. At K transition into canter going large, maintain canter from K through E-H-C-M-B-F-A. On reaching A transition down into trot and then walk.
9. On returning to K repeat steps 6 to 8 two times. Once repeated move onto step 10.
10. At K halt to end the trial.

8.5. Appendix 5. Post-hoc Tukey's test of the effect of Rein Type on Rein Tension (N).

The effect of Rein Type on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.35%.

Difference of Rein Type Levels	**T-Value**	**Adjusted P-Value**
Laced Leather – Continental	-4.76	0.000
Rubber – Continental	0.96	0.875
Thick Leather – Continental	-5.00	0.000
Thin Leather – Continental	-5.84	0.000
Rubber – Laced Leather	5.73	0.000
Thick Leather – Laced Leather	-0.22	0.999
Thin Leather – Laced Leather	-1.08	0.819
Thick Leather – Rubber	-5.96	0.000
Thin Leather - Rubber	-6.80	0.000
Thin Leather – Thick Leather	-0.86	0.913

The effect of Rein Type on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Rein types with the same grouping letter do not differ significantly.

Rein Type	**Mean (N)**	**Grouping**
Rubber	12.910	A
Continental	12.380	A
Laced Leather	9.741	B
Thick Leather	9.618	B
Thin Leather	9.146	B

8.6. Appendix 6. Post-hoc Tukey's test of the effect of Gait on Rein Tension (N).

The effect of Gait on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 98.05%.

Difference of Gait Levels	**T-Value**	**Adjusted P-Value**
Trot-Canter	-7.32	0.000
Walk-Canter	-9.85	0.000
Walk-Trot	-2.54	0.030

The effect of Gait on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Gaits with the same grouping letter do not differ significantly.

Gait	**Mean (N)**	**Grouping**
Walk	13.209	C
Trot	10.078	B
Canter	13.209	A

8.7. Appendix 7. Post-hoc Tukey's test of the effect of Rein Direction on Rein Tension (N).

The effect of Rein Direction on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95.00%.

Difference of Rein Direction Levels	**T-Value**	**Adjusted P-Value**
Left Rein Direction - Right Rein Direction	1.76	0.079

The effect of Rein Direction on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Rein Directions with the same grouping letter do not differ significantly.

Rein Direction	**Mean (N)**	**Grouping**
Left Rein Direction	10.4516	A
Right Rein Direction	11.0662	A

8.8. Appendix 8. Post-hoc Tukey's test of the effect of Rein Hand on Rein Tension (N).

The effect of Rein Hand on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95.00%.

Difference of Rein Hand Levels	**T-Value**	**Adjusted P-Value**
Left Rein Hand - Right Rein Hand	0.43	0.666

The effect of Rein Hand on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Rein Hands with the same grouping letter do not differ significantly.

Rein Hand	**Mean (N)**	**Grouping**
Left Rein Hand	10.683	A
Right Rein Hand	10.834	A

8.9. Appendix 9. Details of the horses tack used in the Bit Type Study.

Horse	**Bridle**	**Noseband**	**Bit Type**
1	Standard Leather	None	Loose-Ring Single Jointed
2	Standard Leather	Cavesson	Loose-Ring Double Jointed
3	Standard Leather	None	Loose-Ring Full Cheek Single Jointed
4	Standard Leather	None	Loose-Ring Full Cheek Single Jointed
5	Standard Leather	None	Loose-Ring Full Cheek Single Jointed
6	Standard Leather	None	Loose-Ring Full Cheek Single Jointed
7	Standard Leather	Crank	Loose-Ring Full Cheek Single Jointed
8	Standard Leather	Crank	Eggbutt Double Jointed (Lozenge)
9	Standard Leather	Cavesson	Loose-Ring Happy Mouth
10	Standard Leather	None	Eggbutt Double Jointed (Ball Joint)
11	Standard Leather	Crank	Loose-Ring Full Cheek Single Jointed
12	Standard Leather	Cavesson	Eggbutt Double Jointed (Lozenge)
13	Micklem™	Micklem™	Eggbutt Single Jointed
14	Standard Leather	Cavesson	Loose-Ring Double Jointed (Bomber)
15	Standard Leather	Cavesson	Loose-Ring Double Jointed (Bomber)
16	Standard Leather	Cavesson	Loose-Ring Double Jointed (Bomber)
17	Standard Leather	Cavesson	Eggbutt Single Jointed
18	Standard Leather	Cavesson	Loose-Ring Double Jointed (Bomber)
19	Standard Leather	Cavesson	Eggbutt Double Jointed (Myler)
20	Standard Leather	Cavesson	Loose-Ring Double Jointed (Lozenge)
21	Standard Leather	Cavesson	Hanging Cheek Double Jointed (Myler)
22	Standard Leather	Cavesson	Loose-Ring Double Jointed (Lozenge)
23	Standard Leather	Cavesson	Hanging Cheek Double Jointed (French-Link)
24	Standard Leather	Cavesson	Loose-Ring Double Jointed (French-Link)
25	Standard Leather	Cavesson	Loose-Ring Single Jointed
26	Standard Leather	Cavesson	Loose-Ring Double Jointed (French-Link)
27	Standard Leather	Cavesson	Eggbutt Single Jointed
28	Standard Leather	Cavesson	Eggbutt Happy Mouth
29	Standard Leather	Drop	Eggbutt Single Jointed

8.10. Appendix 10: The routes trialled by the horse and rider dyads used in the Bit Type Study.

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<tr><th>HR</th><th>Route 1</th><th>Route 2</th></tr>
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Legend: HR = Horse and rider dyad.

= The trial that was carried out by the horse and rider pair.

Route 1 to be carried out for The Bit Type Study

1. From F walk a square F-B-E-K on the left rein.
2. At F repeat step one twice more.
3. From F trot a square F-B-E-K on the left rein.
4. At F repeat step three twice more.
5. At F transition into canter going large, maintain canter from F through B-M-C-H-E-K-A.
6. AT F repeat step five twice more.
7. On returning to F transition into trot and then walk.
8. Change the rein.
9. From K walk a square K-E-B-F on the right rein.
10. At K repeat step nine twice more.
11. From K trot a square K-E-B-F on the right rein.
12. At K repeat step eleven twice more.
13. At K transition into canter going larger, maintain canter from K through E-H-C-M-B-F-A.
14. At K repeat step thirteen twice more.
15. On reaching A transition down into trot and then walk.
16. At K halt to end the trial.

Route 2 to be carried out for The Bit Type Study

1. From K walk a square K-E-B-F on the right rein.
2. At K repeat step nine twice more.
3. From K trot a square K-E-B-F on the right rein.
4. At K repeat step eleven twice more.
5. At K transition into canter going larger, maintain canter from K through E-H-C-M-B-F-A.
6. At K repeat step thirteen twice more.
7. On reaching A transition down into trot and then walk.
8. Change the rein.
9. From F walk a square F-B-E-K on the left rein.
10. At F repeat step one twice more.
11. From F trot a square F-B-E-K on the left rein.
12. At F repeat step three twice more.
13. At F transition into canter going large, maintain canter from F through B-M-C-H-E-K-A.
14. AT F repeat step five twice more.
15. On returning to F transition into trot and then walk.
16. At K halt to end the trial.

8.11. Appendix 11. Post-hoc Tukey's test of the effect of Bit Type on Rein Tension (N).

The effect of Bit Type on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.91%.

Difference of Bit Type Levels	**T-Value**	**Adjusted P-Value**
Eggbutt Double Jointed (Ball Joint) - Eggbutt (Full Cheek) Happy Mouth	-2.37	0.500
Eggbutt Double Jointed (Lozenge) - Eggbutt (Full Cheek) Happy Mouth	2.25	0.589
Eggbutt Double Jointed (Myler) - Eggbutt (Full Cheek) Happy Mouth	-0.24	1.000
Eggbutt Single Jointed - Eggbutt (Full Cheek) Happy Mouth	0.83	1.000
Hanging Cheek Double Jointed (French-Link) - Eggbutt (Full Cheek) Happy Mouth	1.04	0.999
Hanging Cheek Double Jointed (Myler) - Eggbutt (Full Cheek) Happy Mouth	4.02	0.005
Loose Ring (Full Cheek) Single Jointed - Eggbutt (Full Cheek) Happy Mouth	-1.38	0.985
Loose Ring Double Jointed - Eggbutt (Full Cheek) Happy Mouth	3.63	0.020
Loose Ring Double Jointed (Bomber) - Eggbutt (Full Cheek) Happy Mouth	0.64	1.000
Loose Ring Double Jointed (French-Link) - Eggbutt (Full Cheek) Happy Mouth	-0.44	1.000
Loose Ring Double Jointed (Lozenge) - Eggbutt (Full Cheek) Happy Mouth	-0.28	1.000
Loose Ring Happy Mouth - Eggbutt (Full Cheek) Happy Mouth	-0.69	1.000
Loose Ring Single Jointed - Eggbutt (Full Cheek) Happy Mouth	1.59	0.949
Eggbutt Double Jointed (Lozenge) - Eggbutt Double Jointed (Ball Joint)	7.32	0.000
Eggbutt Double Jointed (Myler) - Eggbutt Double Jointed (Ball Joint)	2.08	0.713
Eggbutt Single Jointed - Eggbutt Double Jointed (Ball Joint)	4.72	0.000
Hanging Cheek Double Jointed (French-Link) - Eggbutt Double Jointed (Ball Joint)	3.24	0.071
Hanging Cheek Double Jointed (Myler) - Eggbutt Double Jointed (Ball Joint)	7.29	0.000
Loose Ring (Full Cheek) Single Jointed - Eggbutt Double Jointed (Ball Joint)	2.13	0.683
Loose Ring Double Jointed - Eggbutt Double Jointed (Ball Joint)	8.49	0.000

Loose Ring Double Jointed (Bomber) - Eggbutt Double Jointed (Ball Joint)	4.49	0.001
Loose Ring Double Jointed (French-Link) - Eggbutt Double Jointed (Ball Joint)	2.35	0.521
Loose Ring Double Jointed (Lozenge) - Eggbutt Double Jointed (Ball Joint)	2.63	0.323
Loose Ring Happy Mouth - Eggbutt Double Jointed (Ball Joint)	2.38	0.495
Loose Ring Single Jointed - Eggbutt Double Jointed (Ball Joint)	5.92	0.000
Eggbutt Double Jointed (Myler) - Eggbutt Double Jointed (Lozenge)	-2.56	0.364
Eggbutt Single Jointed - Eggbutt Double Jointed (Lozenge)	-2.27	0.578
Hanging Cheek Double Jointed (French-Link) - Eggbutt Double Jointed (Lozenge)	-0.61	1.000
Hanging Cheek Double Jointed (Myler) - Eggbutt Double Jointed (Lozenge)	3.01	0.136
Loose Ring (Full Cheek) Single Jointed - Eggbutt Double Jointed (Lozenge)	-8.15	0.000
Loose Ring Double Jointed - Eggbutt Double Jointed (Lozenge)	2.48	0.421
Loose Ring Double Jointed (Bomber) - Eggbutt Double Jointed (Lozenge)	-2.62	0.325
Loose Ring Double Jointed (French-Link) - Eggbutt Double Jointed (Lozenge)	-3.53	0.028
Loose Ring Double Jointed (Lozenge) - Eggbutt Double Jointed (Lozenge)	-3.40	0.043
Loose Ring Happy Mouth - Eggbutt Double Jointed (Lozenge)	-4.57	0.000
Loose Ring Single Jointed - Eggbutt Double Jointed (Lozenge)	-1.02	0.999
Eggbutt Single Jointed - Eggbutt Double Jointed (Myler)	1.12	0.998
Hanging Cheek Double Jointed (French-Link) - Eggbutt Double Jointed (Myler)	1.25	0.994
Hanging Cheek Double Jointed (Myler) - Eggbutt Double Jointed (Myler)	4.26	0.002
Loose Ring (Full Cheek) Single Jointed - Eggbutt Double Jointed (Myler)	-1.05	0.999
Loose Ring Double Jointed - Eggbutt Double Jointed (Myler)	3.92	0.007
Loose Ring Double Jointed (Bomber) - Eggbutt Double Jointed (Myler)	0.94	1.000
Loose Ring Double Jointed (French-Link) - Eggbutt Double Jointed (Myler)	-0.17	1.000
Loose Ring Double Jointed (Lozenge) - Eggbutt Double Jointed (Myler)	-0.01	1.000
Loose Ring Happy Mouth - Eggbutt Double Jointed (Myler)	-0.40	1.000

Loose Ring Single Jointed - Eggbutt Double Jointed (Myler)	1.89	0.832
Hanging Cheek Double Jointed (French-Link) - Eggbutt Single Jointed	0.53	1.000
Hanging Cheek Double Jointed (Myler) - Eggbutt Single Jointed	4.21	0.002
Loose Ring (Full Cheek) Single Jointed - Eggbutt Single Jointed	-4.09	0.003
Loose Ring Double Jointed - Eggbutt Single Jointed	4.19	0.002
Loose Ring Double Jointed (Bomber) - Eggbutt Single Jointed	-0.29	1.000
Loose Ring Double Jointed (French-Link) - Eggbutt Single Jointed	-1.63	0.939
Loose Ring Double Jointed (Lozenge) - Eggbutt Single Jointed	-1.45	0.976
Loose Ring Happy Mouth - Eggbutt Single Jointed	-2.22	0.616
Loose Ring Single Jointed - Eggbutt Single Jointed	1.17	0.997
Hanging Cheek Double Jointed (Myler) - Hanging Cheek Double Jointed (French-Link)	2.56	0.370
Loose Ring (Full Cheek) Single Jointed - Hanging Cheek Double Jointed (French-Link)	-2.45	0.444
Loose Ring Double Jointed - Hanging Cheek Double Jointed (French-Link)	1.88	0.837
Loose Ring Double Jointed (Bomber) - Hanging Cheek Double Jointed (French-Link)	-0.70	1.000
Loose Ring Double Jointed (French-Link) - Hanging Cheek Double Jointed (French-Link)	-1.53	0.963
Loose Ring Double Jointed (Lozenge) - Hanging Cheek Double Jointed (French-Link)	-1.40	0.982
Loose Ring Happy Mouth - Hanging Cheek Double Jointed (French-Link)	-1.80	0.876
Loose Ring Single Jointed - Hanging Cheek Double Jointed (French-Link)	0.10	1.000
Loose Ring (Full Cheek) Single Jointed - Hanging Cheek Double Jointed (Myler)	-6.91	0.000
Loose Ring Double Jointed - Hanging Cheek Double Jointed (Myler)	-1.29	0.991
Loose Ring Double Jointed (Bomber) - Hanging Cheek Double Jointed (Myler)	-4.42	0.001
Loose Ring Double Jointed (French-Link) - Hanging Cheek Double Jointed (Myler)	-5.01	0.000
Loose Ring Double Jointed (Lozenge) - Hanging Cheek Double Jointed (Myler)	-4.92	0.000
Loose Ring Happy Mouth - Hanging Cheek Double Jointed (Myler)	-5.61	0.000
Loose Ring Single Jointed - Hanging Cheek Double Jointed (Myler)	-3.49	0.032

Loose Ring Double Jointed - Loose Ring (Full Cheek) Single Jointed	8.98	0.000
Loose Ring Double Jointed (Bomber) - Loose Ring (Full Cheek) Single Jointed	3.79	0.011
Loose Ring Double Jointed (French-Link) - Loose Ring (Full Cheek) Single Jointed	1.12	0.998
Loose Ring Double Jointed (Lozenge) - Loose Ring (Full Cheek) Single Jointed	1.44	0.978
Loose Ring Happy Mouth - Loose Ring (Full Cheek) Single Jointed	0.99	0.999
Loose Ring Single Jointed - Loose Ring (Full Cheek) Single Jointed	5.77	0.000
Loose Ring Double Jointed (Bomber) - Loose Ring Double Jointed	-4.50	0.001
Loose Ring Double Jointed (French-Link) - Loose Ring Double Jointed	-5.05	0.000
Loose Ring Double Jointed (Lozenge) - Loose Ring Double Jointed	-4.97	0.000
Loose Ring Happy Mouth - Loose Ring Double Jointed	-6.11	0.000
Loose Ring Single Jointed - Loose Ring Double Jointed	-3.16	0.090
Loose Ring Double Jointed (French-Link) - Loose Ring Double Jointed (Bomber)	-1.40	0.982
Loose Ring Double Jointed (Lozenge) - Loose Ring Double Jointed (Bomber)	-1.22	0.995
Loose Ring Happy Mouth - Loose Ring Double Jointed (Bomber)	-1.97	0.789
Loose Ring Single Jointed - Loose Ring Double Jointed (Bomber)	1.48	0.971
Loose Ring Double Jointed (Lozenge) - Loose Ring Double Jointed (French-Link)	0.19	1.000
Loose Ring Happy Mouth - Loose Ring Double Jointed (French-Link)	-0.27	1.000
Loose Ring Single Jointed - Loose Ring Double Jointed (French-Link)	2.60	0.340
Loose Ring Happy Mouth - Loose Ring Double Jointed (Lozenge)	-0.50	1.000
Loose Ring Single Jointed - Loose Ring Double Jointed (Lozenge)	2.45	0.445
Loose Ring Single Jointed - Loose Ring Happy Mouth	3.37	0.047

The effect of Bit Type on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Bit types with the same grouping letter do not differ significantly.

Bit Type	**Mean (N)**	**Grouping**
Hanging Cheek Double Jointed (Myler)	18.12	A
Loose Ring Double Jointed	15.881	A B
Eggbutt Double Jointed (Lozenge)	13.247	A B C
Loose Ring Single Jointed	12.262	B C D
Hanging Cheek Double Jointed (French-Link)	12.058	A B C D E F
Eggbutt Single Jointed	10.991	C D E
Loose Ring Double Jointed (Bomber)	10.674	C D E
Eggbutt (Full Cheek) Happy Mouth	9.594	C D E F
Eggbutt Double Jointed (Myler)	9.091	C D E F
Loose Ring Double Jointed (Lozenge)	9.08	D E F
Loose Ring Double Jointed (French-Link)	8.782	D E F
Loose Ring Happy Mouth	8.399	E F
Loose Ring (Full Cheek) Single Jointed	7.473	F
Eggbutt Double Jointed (Ball Joint)	5.483	F

8.12. Appendix 12. Post-hoc Tukey's test of the effect of Bit Type (Ring) on Rein Tension (N).

The effect of Bit Type (Ring) on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.35%.

Difference of Bit Type (Ring) Levels	T-Value	Adjusted P-Value
Eggbutt (Full Cheek) – Eggbutt	-0.62	0.972
Hanging Cheek - Eggbutt	3.81	0.001
Loose Ring – Eggbutt	0.89	0.900
Loose Ring (Full Cheek) - Eggbutt	-5.42	0.000
Hanging Cheek – Eggbutt (Full Cheek)	2.98	0.024
Loose Ring – Eggbutt (Full Cheek)	0.94	0.883
Loose Ring (Full Cheek) – Eggbutt (Full Cheek)	-1.27	0.708
Loose Ring – Hanging Cheek	-3.64	0.005
Loose Ring (Full Cheek) – Hanging Cheek	-6.26	0.000
Loose Ring (Full Cheek) – Loose Ring	-6.77	0.000

The effect of Bit Type (Ring) on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Bit types with the same grouping letter do not differ significantly.

Bit Type (Ring)	Mean (N)	Grouping
Hanging Cheek	15.696	A
Loose Ring	11.154	B
Eggbutt	10.634	B
Eggbutt (Full Cheek)	9.594	B C
Loose Ring (Full Cheek)	7.473	C

8.13. Appendix 13. Post-hoc Tukey’s test of the effect of Bit Type (Joint) on Rein Tension (N).

The effect of Bit Type (Joint) on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.75%.

Difference of Bit Type (joint) Levels	**T-Value**	**Adjusted P-Value**
Double Jointed (Ball Joint) - Double Jointed	-8.04	0.000
Double Jointed (Bomber) - Double Jointed	-4.27	0.001
Double Jointed (French-Link) - Double Jointed	-4.59	0.000
Double Jointed (Lozenge) - Double Jointed	-3.43	0.014
Double Jointed (Myler) - Double Jointed	-1.57	0.766
Happy Mouth - Double Jointed	-5.94	0.000
Single Jointed - Double Jointed	-7.40	0.000
Double Jointed (Bomber) - Double Jointed (Ball Joint)	4.25	0.001
Double Jointed (French-Link) - Double Jointed (Ball Joint)	3.08	0.043
Double Jointed (Lozenge) - Double Jointed (Ball Joint)	6.27	0.000
Double Jointed (Myler) - Double Jointed (Ball Joint)	5.62	0.000
Happy Mouth - Double Jointed (Ball Joint)	2.66	0.135
Single Jointed - Double Jointed (Ball Joint)	3.36	0.018
Double Jointed (French-Link) - Double Jointed (Bomber)	-0.79	0.994
Double Jointed (Lozenge) - Double Jointed (Bomber)	1.56	0.775
Double Jointed (Myler) - Double Jointed (Bomber)	2.12	0.400
Happy Mouth - Double Jointed (Bomber)	-1.75	0.657
Single Jointed - Double Jointed (Bomber)	-2.24	0.327
Double Jointed (Lozenge) - Double Jointed (French-Link)	2.22	0.338
Double Jointed (Myler) - Double Jointed (French-Link)	2.63	0.145
Happy Mouth - Double Jointed (French-Link)	-0.75	0.995
Single Jointed - Double Jointed (French-Link)	-0.88	0.988

Double Jointed (Myler) - Double Jointed (Lozenge)	1.12	0.953
Happy Mouth - Double Jointed (Lozenge)	-3.62	0.007
Single Jointed - Double Jointed (Lozenge)	-5.42	0.000
Happy Mouth - Double Jointed (Myler)	-3.58	0.008
Single Jointed - Double Jointed (Myler)	-4.19	0.001
Single Jointed - Happy Mouth	0.04	1.000

The effect of Bit Type (Joint) on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Bit types with the same grouping letter do not differ significantly.

Bit Type (Joint)	**Mean (N)**	**Grouping**
Double Jointed	15.881	A
Double Jointed (Myler)	13.606	A B
Double Jointed (Lozenge)	12.206	B
Double Jointed (Bomber)	10.674	B C
Double Jointed (French-Link)	9.646	B C
Single Jointed	8.73	C
Happy Mouth	8.698	C D
Double Jointed (Ball Joint)	5.483	D

8.14. Appendix 14. Post-hoc Tukey's test of the effect of Gait on Rein Tension (N).

The effect of Gait on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.75%.

Difference of Gait Levels	**T-Value**	**Adjusted P-Value**
Trot - Canter	-3.94	0.000
Walk - Canter	-6.72	0.000
Walk - Trot	-2.82	0.013

The effect of Gait on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Gaits with the same grouping letter do not differ significantly.

Gait	**Mean (N)**	**Grouping**
Walk	8.102	C
Trot	9.676	B
Canter	11.898	A

8.15. Appendix 15. Post-hoc Tukey's test of the effect of Rein Hand on Rein Tension (N).

The effect of Rein Hand on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95%.

Difference of Rein Hand Levels	**T-Value**	**Adjusted P-Value**
Right Rein Hand – Left Rein Hand	-0.72	0.474

The effect of Rein Hand on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Hands with the same grouping letter do not differ significantly.

Rein Hand	**Mean (N)**	**Grouping**
Left Rein Hand	10.058	A
Right Rein Hand	9.729	A

8.16. Appendix 16. Post-hoc Tukey's test of the effect of Rein Direction on Rein Tension (N).

The effect of Rein Direction on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95%.

Difference of Rein Direction Levels	T-Value	Adjusted P-Value
Right Rein Direction – Left Rein Direction	1.89	0.059

The effect of Rein Direction on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Directions with the same grouping letter do not differ significantly.

Rein Direction	Mean (N)	Grouping
Left Rein Hand	10.327	A
Right Rein Direction	9.46	A

8.17. Appendix 17. Post-hoc Tukey's test of the effect of Horse Age on Rein Tension (N).

The effect of Horse Age on rein tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.9%.

Difference of Horse Age (Years) Levels	T-Value	Adjusted P-Value
7 - 6	-0.58	1.000
8 - 6	4.76	0.000
9 - 6	0.70	1.000
10 - 6	2.57	0.328
11 - 6	-2.96	0.137
12 - 6	2.50	0.372
13 - 6	-4.05	0.004
15 - 6	1.57	0.939
17 - 6	-2.45	0.412
18 - 6	1.34	0.983
22 - 6	-0.73	1.000
23 - 6	4.58	0.000
8 - 7	5.45	0.000
9 - 7	1.42	0.971
10 - 7	3.33	0.048
11 - 7	-2.32	0.500
12 - 7	3.07	0.102
13 - 7	-3.38	0.041
15 - 7	2.12	0.648
17 - 7	-1.70	0.894
18 - 7	1.75	0.876
22 - 7	-0.09	1.000
23 - 7	5.06	0.000
9 - 8	-5.85	0.000
10 - 8	-3.77	0.010
11 - 8	-9.15	0.000
12 - 8	-1.65	0.915
13 - 8	-11.17	0.000
15 - 8	-2.61	0.302
17 - 8	-10.57	0.000
18 - 8	-1.61	0.928
22 - 8	-6.37	0.000
23 - 8	1.49	0.959
10 - 9	2.94	0.142
11 - 9	-4.72	0.000
12 - 9	2.41	0.436
13 - 9	-6.49	0.000
15 - 9	1.26	0.989
17 - 9	-4.90	0.000

18 - 9	1.04	0.998
22 - 9	-1.78	0.862
23 - 9	4.73	0.000
11 - 10	-7.21	0.000
12 - 10	0.75	1.000
13 - 10	-9.45	0.000
15 - 10	-0.39	1.000
17 - 10	-8.74	0.000
18 - 10	-0.06	1.000
22 - 10	-4.07	0.003
23 - 10	3.50	0.028
12 - 11	5.61	0.000
13 - 11	-1.06	0.998
15 - 11	4.50	0.001
17 - 11	1.18	0.994
18 - 11	3.39	0.039
22 - 11	2.49	0.379
23 - 11	7.20	0.000
13 - 12	-6.80	0.000
15 - 12	-0.85	1.000
17 - 12	-5.52	0.000
18 - 12	-0.47	1.000
22 - 12	-3.44	0.033
23 - 12	2.45	0.405
15 - 13	5.59	0.000
17 - 13	2.65	0.278
18 - 13	4.08	0.003
22 - 13	3.72	0.013
23 - 13	8.16	0.000
17 - 15	-4.22	0.002
18 - 15	0.17	1.000
22 - 15	-2.39	0.449
23 - 15	3.13	0.085
18 - 17	2.99	0.125
22 - 17	1.87	0.813
23 - 17	7.14	0.000
22 - 18	-1.89	0.804
23 - 18	2.35	0.477
23 - 22	5.44	0.000

The effect of Horse Age on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Years with the same grouping letter do not differ significantly.

Horse Age (Years)	Mean (N)	Grouping
23	17.392	A
8	15.059	A
12	13.02	A B C
10	12.171	B
18	12.058	A B C D E
15	11.711	A B C D
9	10.154	B C D
6	9.352	B C D E F
7	8.521	C D E F
22	8.399	D E F
17	6.613	E F G
11	5.483	F G
13	4.328	G

8.18. Appendix 18. Post-hoc Tukey's test of the effect of Horse Gender on Rein Tension (N).

The effect of Horse Gender on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95%.

Difference of Horse Gender Levels	T-Value	Adjusted P-Value
Mare - Gelding	-6.34	0.000

The effect of Horse Gender on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Genders with the same grouping letter do not differ significantly.

Horse Gender	Mean (N)	Grouping
Gelding	11.179	A
Mare	8.242	B

8.19. Appendix 19. Post-hoc Tukey’s test of the effect of Horse Breed on Rein Tension (N).

The effect of Horse Breed on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.95%.

Difference of Horse Breed Levels	**T-Value**	**Adjusted P-Value**
Argentine Polo Pony - Andalusian	-1.80	0.943
British Riding Pony - Andalusian	5.73	0.000
Cob - Andalusian	0.14	1.000
Cob X - Andalusian	1.02	1.000
Hackney X Welsh Cob - Andalusian	0.81	1.000
Irish Draught - Andalusian	5.59	0.000
Irish Draught X Welsh D - Andalusian	-1.06	1.000
Irish Sports Horse - Andalusian	1.25	0.999
Irish Sports Horse X Andalusian - Andalusian	1.53	0.988
Lustiano - Andalusian	1.48	0.992
New Forest X Arab - Andalusian	4.33	0.002
Sports Horse - Andalusian	2.03	0.857
Thoroughbred - Andalusian	4.18	0.004
Unknown - Andalusian	2.92	0.241
Warmblood - Andalusian	1.82	0.940
Warmblood X - Andalusian	3.80	0.017
Welsh X Arab - Andalusian	5.35	0.000
British Riding Pony - Argentine Polo Pony	9.49	0.000
Cob - Argentine Polo Pony	2.57	0.480
Cob X - Argentine Polo Pony	3.17	0.129
Hackney X Welsh Cob - Argentine Polo Pony	4.25	0.003
Irish Draught - Argentine Polo Pony	12.53	0.000
Irish Draught X Welsh D - Argentine Polo Pony	1.02	1.000
Irish Sports Horse - Argentine Polo Pony	3.48	0.052
Irish Sports Horse X Andalusian - Argentine Polo Pony	5.51	0.000
Lustiano - Argentine Polo Pony	5.42	0.000
New Forest X Arab - Argentine Polo Pony	7.61	0.000
Sports Horse - Argentine Polo Pony	4.52	0.001
Thoroughbred - Argentine Polo Pony	7.08	0.000
Unknown - Argentine Polo Pony	7.64	0.000
Warmblood - Argentine Polo Pony	7.27	0.000
Warmblood X - Argentine Polo Pony	12.72	0.000
Welsh X Arab - Argentine Polo Pony	8.98	0.000
Cob - British Riding Pony	-6.38	0.000
Cob X - British Riding Pony	-4.71	0.000
Hackney X Welsh Cob - British Riding Pony	-6.21	0.000
Irish Draught - British Riding Pony	-1.43	0.995
Irish Draught X Welsh D - British Riding Pony	-8.08	0.000

Irish Sports Horse - British Riding Pony	-4.48	0.001
Irish Sports Horse X Andalusian - British Riding Pony	-5.49	0.000
Lustiano - British Riding Pony	-5.54	0.000
New Forest X Arab - British Riding Pony	-1.40	0.996
Sports Horse - British Riding Pony	-3.71	0.024
Thoroughbred - British Riding Pony	-1.28	0.998
Unknown - British Riding Pony	-3.99	0.008
Warmblood - British Riding Pony	-5.67	0.000
Warmblood X - British Riding Pony	-3.92	0.011
Welsh X Arab - British Riding Pony	-0.38	1.000
Cob X - Cob	1.02	1.000
Hackney X Welsh Cob - Cob	0.80	1.000
Irish Draught - Cob	6.69	0.000
Irish Draught X Welsh D - Cob	-1.49	0.991
Irish Sports Horse - Cob	1.28	0.999
Irish Sports Horse X Andalusian - Cob	1.70	0.967
Lustiano - Cob	1.64	0.977
New Forest X Arab - Cob	4.78	0.000
Sports Horse - Cob	2.16	0.779
Thoroughbred - Cob	4.56	0.001
Unknown - Cob	3.38	0.070
Warmblood - Cob	2.11	0.810
Warmblood X - Cob	4.73	0.000
Welsh X Arab - Cob	5.94	0.000
Hackney X Welsh Cob - Cob X	-0.44	1.000
Irish Draught - Cob X	4.34	0.002
Irish Draught X Welsh D - Cob X	-2.31	0.679
Irish Sports Horse - Cob X	0.23	1.000
Irish Sports Horse X Andalusian - Cob X	0.28	1.000
Lustiano - Cob X	0.23	1.000
New Forest X Arab - Cob X	3.31	0.087
Sports Horse - Cob X	1.01	1.000
Thoroughbred - Cob X	3.21	0.116
Unknown - Cob X	1.69	0.969
Warmblood - Cob X	0.49	1.000
Warmblood X - Cob X	2.43	0.588
Welsh X Arab - Cob X	4.33	0.002
Irish Draught - Hackney X Welsh Cob	6.76	0.000
Irish Draught X Welsh D - Hackney X Welsh Cob	-2.64	0.426
Irish Sports Horse - Hackney X Welsh Cob	0.73	1.000
Irish Sports Horse X Andalusian - Hackney X Welsh Cob	1.03	1.000
Lustiano - Hackney X Welsh Cob	0.96	1.000
New Forest X Arab - Hackney X Welsh Cob	4.50	0.001

Sports Horse - Hackney X Welsh Cob	1.68	0.971
Thoroughbred - Hackney X Welsh Cob	4.26	0.003
Unknown - Hackney X Welsh Cob	2.96	0.218
Warmblood - Hackney X Welsh Cob	1.46	0.993
Warmblood X - Hackney X Welsh Cob	4.63	0.001
Welsh X Arab - Hackney X Welsh Cob	5.75	0.000
Irish Draught X Welsh D - Irish Draught	-9.40	0.000
Irish Sports Horse - Irish Draught	-4.06	0.006
Irish Sports Horse X Andalusian - Irish Draught	-5.73	0.000
Lustiano - Irish Draught	-5.81	0.000
New Forest X Arab - Irish Draught	-0.29	1.000
Sports Horse - Irish Draught	-3.11	0.153
Thoroughbred - Irish Draught	-0.20	1.000
Unknown - Irish Draught	-3.60	0.035
Warmblood - Irish Draught	-6.31	0.000
Warmblood X - Irish Draught	-3.73	0.022
Welsh X Arab - Irish Draught	0.97	1.000
Irish Sports Horse - Irish Draught X Welsh D	2.59	0.461
Irish Sports Horse X Andalusian - Irish Draught X Welsh D	3.66	0.028
Lustiano - Irish Draught X Welsh D	3.59	0.035
New Forest X Arab - Irish Draught X Welsh D	6.36	0.000
Sports Horse - Irish Draught X Welsh D	3.54	0.042
Thoroughbred - Irish Draught X Welsh D	6.00	0.000
Unknown - Irish Draught X Welsh D	5.52	0.000
Warmblood - Irish Draught X Welsh D	4.49	0.001
Warmblood X - Irish Draught X Welsh D	7.89	0.000
Welsh X Arab - Irish Draught X Welsh D	7.61	0.000
Irish Sports Horse X Andalusian - Irish Sports Horse	0.00	1.000
Lustiano - Irish Sports Horse	-0.05	1.000
New Forest X Arab - Irish Sports Horse	3.08	0.164
Sports Horse - Irish Sports Horse	0.78	1.000
Thoroughbred - Irish Sports Horse	2.99	0.205
Unknown - Irish Sports Horse	1.41	0.995
Warmblood - Irish Sports Horse	0.18	1.000
Warmblood X - Irish Sports Horse	2.12	0.808
Welsh X Arab - Irish Sports Horse	4.10	0.005
Lustiano - Irish Sports Horse X Andalusian	-0.07	1.000
New Forest X Arab - Irish Sports Horse X Andalusian	3.77	0.019
Sports Horse - Irish Sports Horse X Andalusian	0.95	1.000
Thoroughbred - Irish Sports Horse X Andalusian	3.58	0.037
Unknown - Irish Sports Horse X Andalusian	1.96	0.886
Warmblood - Irish Sports Horse X Andalusian	0.28	1.000
Warmblood X - Irish Sports Horse X Andalusian	3.36	0.075

Welsh X Arab - Irish Sports Horse X Andalusian	5.02	0.000
New Forest X Arab - Lustiano	3.82	0.016
Sports Horse - Lustiano	1.00	1.000
Thoroughbred - Lustiano	3.63	0.032
Unknown - Lustiano	2.03	0.853
Warmblood - Lustiano	0.36	1.000
Warmblood X - Lustiano	3.45	0.057
Welsh X Arab - Lustiano	5.07	0.000
Sports Horse - New Forest X Arab	-2.30	0.682
Thoroughbred - New Forest X Arab	0.05	1.000
Unknown - New Forest X Arab	-2.30	0.683
Warmblood - New Forest X Arab	-3.84	0.015
Warmblood X - New Forest X Arab	-2.03	0.855
Welsh X Arab - New Forest X Arab	1.02	1.000
Thoroughbred - Sports Horse	2.25	0.720
Unknown - Sports Horse	0.48	1.000
Warmblood - Sports Horse	-0.83	1.000
Warmblood X - Sports Horse	1.07	1.000
Welsh X Arab - Sports Horse	3.33	0.083
Unknown - Thoroughbred	-2.21	0.745
Warmblood - Thoroughbred	-3.62	0.033
Warmblood X - Thoroughbred	-1.94	0.898
Welsh X Arab - Thoroughbred	0.92	1.000
Warmblood - Unknown	-1.97	0.883
Warmblood X - Unknown	0.82	1.000
Welsh X Arab - Unknown	3.53	0.043
Warmblood X - Warmblood	3.86	0.014
Welsh X Arab - Warmblood	5.18	0.000
Welsh X Arab - Warmblood X	3.41	0.065

The effect of Horse Breed on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Breeds with the same grouping letter do not differ significantly.

Horse Breed	**Mean (N)**	**Grouping**
British Riding Pony	18.12	A
Welsh X Arab	17.392	A B C
Irish Draught	15.881	A C
Thoroughbred	15.541	A B C D
New Forest X Arab	15.432	A B C D
Warmblood X	12.544	B D E
Unknown	11.777	D E F
Sports Horse	11.021	B C D E F
Warmblood	9.803	F
Irish Sports Horse X Andalusian	9.537	E F
Irish Sports Horse	9.534	D E F G H
Lustiano	9.458	E F
Cob X	9.091	D E F G H
Hackney X Welsh Cob	8.399	F G
Cob	7.381	F G H
Andalusian	7.139	F G H
Irish Draught X Welsh D	5.4828	G H
Argentine Polo Pony	4.5642	H

8.20. Appendix 20. Post-hoc Tukey's test of the effect of Horse Height on Rein Tension (N).

The effect of Horse Height on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95%.

Difference of Horse Height (hh) Levels	T-Value	Adjusted P-Value
14.1 - 14.0	2.03	0.675
14.2 - 14.0	2.72	0.215
14.3 - 14.0	2.04	0.668
15.0 - 14.0	3.73	0.010
15.1 - 14.0	1.86	0.784
15.2 - 14.0	0.84	1.000
16.0 - 14.0	1.26	0.983
16.1 - 14.0	3.33	0.041
16.2 - 14.0	4.38	0.001
16.3 - 14.0	2.16	0.576
17.0 - 14.0	3.25	0.053
14.2 - 14.1	0.53	1.000
14.3 - 14.1	0.24	1.000
15.0 - 14.1	1.93	0.743
15.1 - 14.1	-0.58	1.000
15.2 - 14.1	-2.06	0.652
16.0 - 14.1	-0.57	1.000
16.1 - 14.1	1.26	0.984
16.2 - 14.1	2.74	0.208
16.3 - 14.1	0.47	1.000
17.0 - 14.1	1.35	0.973
14.3 - 14.2	-0.15	1.000
15.0 - 14.2	2.03	0.670
15.1 - 14.2	-1.62	0.901
15.2 - 14.2	-4.10	0.002
16.0 - 14.2	-1.05	0.997
16.1 - 14.2	1.17	0.991
16.2 - 14.2	3.34	0.040
16.3 - 14.2	0.14	1.000
17.0 - 14.2	1.19	0.990
15.0 - 14.3	1.32	0.977
15.1 - 14.3	-0.75	1.000
15.2 - 14.3	-1.94	0.735
16.0 - 14.3	-0.72	1.000
16.1 - 14.3	0.71	1.000
16.2 - 14.3	1.94	0.733
16.3 - 14.3	0.22	1.000
17.0 - 14.3	0.87	0.999

15.1 - 15.0	-3.42	0.031
15.2 - 15.0	-5.76	0.000
16.0 - 15.0	-2.11	0.618
16.1 - 15.0	-1.32	0.977
16.2 - 15.0	0.97	0.998
16.3 - 15.0	-0.95	0.999
17.0 - 15.0	-0.62	1.000
15.2 - 15.1	-2.16	0.576
16.0 - 15.1	-0.20	1.000
16.1 - 15.1	3.00	0.109
16.2 - 15.1	4.80	0.000
16.3 - 15.1	0.97	0.998
17.0 - 15.1	2.49	0.344
16.0 - 15.2	0.86	0.999
16.1 - 15.2	6.35	0.000
16.2 - 15.2	7.64	0.000
16.3 - 15.2	2.07	0.643
17.0 - 15.2	4.51	0.000
16.1 - 16.0	1.59	0.912
16.2 - 16.0	2.70	0.225
16.3 - 16.0	0.90	0.999
17.0 - 16.0	1.67	0.884
16.2 - 16.1	2.81	0.176
16.3 - 16.1	-0.35	1.000
17.0 - 16.1	0.43	1.000
16.3 - 16.2	-1.51	0.937
17.0 - 16.2	-1.55	0.926
17.0 - 16.3	0.54	1.000

The effect of Horse Height on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Heights with the same grouping letter do not differ significantly.

Horse Height (hh)	Mean (N)	Grouping
16.2	12.981	A
15.0	11.969	A B
17.0	11.205	A B C D
16.1	10.769	A B C
16.3	10.126	A B C D E
14.2	9.854	B C D
14.3	9.594	A B C D E
14.1	9.107	A B C D E
15.1	8.271	C D E
16.0	7.88	A B C D E
15.2	6.282	E
14.0	4.725	D E

8.21. Appendix 21. Post-hoc Tukey's test of the effect of Rider Age on Rein Tension (N).

The effect of Rider Age on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.75%.

Difference of Rider Age (Years) Levels	**T-Value**	**Adjusted P-Value**
23 - 22	-2.75	0.107
24 - 22	1.53	0.790
26 - 22	1.17	0.939
48 - 22	-6.79	0.000
49 - 22	-5.57	0.000
53 - 22	-6.89	0.000
63 - 22	2.05	0.451
24 - 23	4.47	0.000
26 - 23	3.81	0.003
48 - 23	-4.11	0.001
49 - 23	-3.41	0.015
53 - 23	-4.21	0.001
63 - 23	5.00	0.000
26 - 24	-0.21	1.000
48 - 24	-8.71	0.000
49 - 24	-6.98	0.000
53 - 24	-8.81	0.000
63 - 24	0.55	0.999
48 - 26	-7.67	0.000
49 - 26	-6.37	0.000
53 - 26	-7.76	0.000
63 - 26	0.70	0.997
49 - 48	-0.08	1.000
53 - 48	-0.09	1.000
63 - 48	9.23	0.000
53 - 49	0.00	1.000
63 - 49	7.38	0.000
63 - 53	9.34	0.000

The effect of Rider Age on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Years with the same grouping letter do not differ significantly.

Rider Age (Years)	Mean (N)	Grouping
63	12.782	A
24	12.398	A
26	12.227	A
22	11.232	A B
23	8.995	B
48	5.563	C
53	5.483	C
49	5.483	C

8.22. Appendix 22. Post-hoc Tukey's test of the effect of Rider Gender on Rein Tension (N).

The effect of Rider Gender on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 95%.

Difference of Rider Gender Levels	T-Value	Adjusted P-Value
Male - Female	4.92	0.000

The effect of Rider Gender on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Genders with the same grouping letter do not differ significantly.

Rider Gender	Mean ± SE (N)	Minimum (N)	Maximum (N)	Grouping
Female	9.346±0.264	1.192	43.926	A
Male	12.398±0.474	4.46	24.233	B

8.23. Appendix 23. Post-hoc Tukey's test of the effect of Ridden For (years) on Rein Tension (N).

The effect of Ridden For (years) on Rein Tension (N). Tukey Simultaneous Tests for Differences of Means. Individual confidence level = 99.83%.

Difference of Ridden For (Years) Levels	**T-Value**	**Adjusted P-Value**
4 - 3	2.32	0.373
8 - 3	9.96	0.000
12 - 3	6.21	0.000
15 - 3	9.16	0.000
20 - 3	8.42	0.000
38 - 3	4.78	0.000
40 - 3	2.68	0.180
53 - 3	10.56	0.000
60 - 3	7.15	0.000
8 - 4	7.12	0.000
12 - 4	3.48	0.018
15 - 4	6.50	0.000
20 - 4	5.69	0.000
38 - 4	2.46	0.291
40 - 4	0.00	1.000
53 - 4	7.87	0.000
60 - 4	4.82	0.000
12 - 8	-4.57	0.000
15 - 8	-0.22	1.000
20 - 8	-1.57	0.865
38 - 8	-4.12	0.002
40 - 8	-9.00	0.000
53 - 8	1.53	0.882
60 - 8	-1.23	0.968
15 - 12	3.89	0.004
20 - 12	2.81	0.132
38 - 12	-0.59	1.000
40 - 12	-4.29	0.001
53 - 12	5.60	0.000
60 - 12	2.19	0.465
20 - 15	-1.20	0.973
38 - 15	-3.69	0.009
40 - 15	-7.92	0.000
53 - 15	1.58	0.858
60 - 15	-0.99	0.993
38 - 20	-2.80	0.135
40 - 20	-7.03	0.000

53 - 20	2.86	0.117
60 - 20	-0.03	1.000
40 - 38	-2.84	0.124
53 - 38	5.03	0.000
60 - 38	2.37	0.347
53 - 40	9.64	0.000
60 - 40	5.57	0.000
60 - 53	-2.30	0.387

The effect of Ridden For (years) on Rein Tension (N). Grouping Information Using the Tukey Method and 95% Confidence. Years with the same grouping letter do not differ significantly.

Ridden For (Years)	Mean	Grouping
53	13.571	A
8	12.398	A
15	12.227	A
20	11.232	A B
60	11.205	A B
12	8.995	B
38	8.399	B C
40	5.483	C D
4	5.483	C D
3	2.726	D

8.24. Appendix 24. The effect of Rein Direction and Rein Hand on Rein Tension (N).

The effect of Rein Direction and Rein Hand on Rein Tension (N) (Rein Type)

REIN TYPE	**Left Rein Hand**	**Right Rein Hand**
Left Rein Direction	10.81±0.356	10.104±0.349
Right Rein Direction	10.558±0.406	11.568±0.389

The effect of Rein Direction and Rein Hand on Rein Tension (N) (Bit Type)

BIT TYPE	**Left Rein Hand**	**Right Rein Hand**
Left Rein Direction	9.998±0.477	8.922±0.413
Right Rein Direction	10.063±0.513	10.487±0.490